State of California

THE RESOURCES AGENCY

Department of Water Resources

BULLETIN No. 112

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SEPTEMBER 1964

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
Department of Water Resources

San Diego River at Lakeside—1916 Flood

Historical collection, Title Insurance and Trust Company, Union Title Office

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EPARTMENT OF WATER RESOURCES
O. BOX 388
CRAMENTO

June 16, 1964

Honorable Edmund G. Brown, Governor,
and Members of the Legislature of the
State of California
State Capitol
Sacramento, California

Mr. Robert C. Dent, Chairman
Board of Supervisors
County of San Diego
Courthouse
San Diego, California

Gentlemen:

I am pleased to transmit herewith State Department of Water Resources Bulletin No. 112, entitled "San Diego County Flood Hazard Investigation." The investigation that is reported in this bulletin was conducted in accordance with "Cooperative Agreement Between the State of California, Department of Water Resources and the County of San Diego," dated June 26, 1961, and Amendment No. 1 to this agreement dated June 25, 1963. Bulletin No. 112 is being submitted in accordance with that agreement.

The purpose of the investigation was to delineate areas of potential inundation along portions of the San Luis Rey, San Dieguito, San Diego, Sweetwater, and Otay Rivers in San Diego County for floods of 50- and 100-year recurrence intervals. Maps illustrating these areas of potential flooding are presented in the report, together with a detailed exposition of the techniques used in determining areas of inundation. Appendix A to Bulletin No. 112, entitled "Regional Flood Frequency Analysis," which was transmitted to San Diego County on August 5, 1963, contains a description of the methodology of regional flood frequency analyses and the results of their application in determining peak flood flows.

We have also included a discussion of the need for management of land use and a brief description of what local, state, and federal agencies are doing to reduce flood damage in San Diego County.

Honorable Edmund G. Brown, Governor,
and Members of the Legislature of the
State of California

Mr. Robert C. Dent, Chairman
Board of Supervisors
County of San Diego

The information presented in the bulletin should serve as a guide to the reduction of the flood damage potential in the development of the river valleys of San Diego County.

Sincerely yours,

William E. Warne

Director

ACKNOWLEDGMENT

Valuable assistance and data used in this investigation were contributed by numerous public agencies, private companies, and individuals. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

U. S. Geological Survey, Water Resources Division,
Menlo Park, California

Mr. B. H. Hoffmaster, Flood Control Engineer,
County of San Diego

Dr. Anatol Balbach, Associate Professor of Economics,
San Fernando Valley State College

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

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ALFRED R. GOLZE', Chief Engineer
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SAN DIEGO COUNTY

Board of Supervisors

ROBERT C. DENT, Chairman

DE GRAFF AUSTIN

DAVID W. BIRD

ROBERT C. COZENS

FRANK A. GIBSON

- - - - - - - - - - - - -

WARREN A. BARNEY, Director of Special District Services

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CHAPTER I. INTRODUCTION

During the past two decades, San Diego County has experienced explosive urbanization of its coastal areas. The population of the county has more than tripled during this period. This burgeoning development is presently expanding into the river valleys of the coastal streams. Large portions of these river valleys are within floodplains and are subject to varying degrees of inundation from flood flows.

As previous flood control studies conducted in San Diego County did not adequately delineate the extent of floodplains, local authorities have not had available all of the data necessary for guiding the urban growth within the river valleys. Not only does encroachment on potential areas of inundation create a threat to lives and property, but substantially increases the costs of any subsequent flood control improvements. Accordingly, an investigation was initiated by the State Department of Water Resources, at the request of the county, to delineate the areas subject to flooding along certain portions of the major coastal streams in San Diego County. The results of the investigation are presented in this report.

Authorization for Investigation

The Department of Water Resources is authorized by the California Water Code, Division 6, Part 6, Chapters 1 and 2, known as "The State Water Resources Law of 1945," to make investigations of the water resources of the State, formulate plans for the control, conservation, protection, and utilization of such water resources, and to report on its findings. When requested, the department may enter into a cooperative agreement with any county, city, state agency, or public district to expend money on behalf of the cooperator to accomplish the purposes of the law.

The State of California, Department of Water Resources, and the County of San Diego entered into such a cooperative agreement and each contributed the sum of $53,000 to finance the investigation by the department of potential flood hazards of portions of coastal San Diego County. A copy of this agreement is appended to this report as Appendix H.

Objectives and Scope of Investigation and Report

The objectives of this investigation were to determine the peak discharges of floods of 50- and 100-year recurrence intervals and to delineate the potential inundated areas for present cultural conditions for each recurrence interval along specific reaches of the San Luis Rey, San Dieguito, San Diego, Sweetwater, and Otay Rivers in San Diego County.

To accomplish these objectives, the study was divided into two basic parts: (1) analysis of regional hydrology; and (2) determination of areas of potential inundation.

Regional hydrology studies were performed for the purpose of producing reliable estimates of peak flood discharges for the 50- and 100-year recurrence intervals for ungaged drainage areas located in coastal San Diego County. In estimating these discharges, it was necessary to consider floods of more frequent recurrence and synthesize or extend runoff records by correlation with runoff data from streams tributary to the study area and from streams in adjacent watersheds. A detailed description of this study and the results thereof are presented in Appendix A, entitled "Regional Flood Frequency Analysis," which has been previously published by the department in March 1963.

The second part of the study utilized the estimates of peak flood flows established from the regional flood frequency analysis to determine the potential floods and areas of inundation for portions of the streams in the study areas. The work necessary to accomplish this objective consisted of determining hydraulic properties of the flood channels at selected intervals, results of reservoir and stream channel routing, backwater conditions, and water-surface profiles for flood peaks of 50- and 100-year recurrence intervals. Water-surface profiles were plotted on large-scale maps to indicate the areas of potential inundation.

To insure that San Diego County and other interested agencies received information on areas of potential inundation as soon as possible, the department on April 1, 1962 contracted with the U. S. Geological Survey to determine the areas subject to inundation from the 50- and 100-year floods for those portions of the San Luis Rey and San Dieguito Rivers under study. In its investigation, the U. S. Geological Survey utilized the methods set forth in Appendix A. The department carried out the analyses and delineated the areas of inundation within the San Diego, Sweetwater, and Otay River Basins. A detailed description of the techniques employed for determining areas of potential inundation is presented in Appendix B, entitled "Methods and Procedures."

A summary of the results of this investigation is presented in Chapter III of the text of the report, and detailed supporting data are presented in Appendixes C through G. Each of these appendixes presents the results of the flood routing for one of the five streams studied and shows the areas of potential inundation for various conditions of initial reservoir storage. The areas are delineated on plates bound at the end of each appendix. Appendixes F and G were prepared by the U. S. Geological Survey. In Appendix H, the cooperative agreement between the State of California and the County of San Diego authorizing the investigation and report is reproduced. A bibliography is presented in Appendix I.

Related Investigations and Reports

The State Department of Water Resources, including its predecessor, the Division of Water Resources, and the U. S. Army Corps of Engineers, have prepared a number of reports on the coastal San Diego County area which include data on flood potential. These reports were reviewed and use was made of pertinent material and data contained therein. Principal reports which were utilized are as follows:

State of California, State Water Resources Board. Bulletin No. 1, "Water Resources of California," 1951.

State of California, Department of Public Works, Division of Water Resources. Bulletin No. 48, "San Diego County Investigation," 1935.

----. Bulletin No. 48-A, "San Luis Rey River Investigation," 1936.

----. Bulletin No. 55, "San Dieguito and San Diego Rivers Investigation," 1949.

State of California, Department of Water Resources, Bulletin No. 72, "San Dieguito River Investigation," 1959.

United States Army, Corps of Engineers. "Appendixes to Accompany Report on Survey, Flood Control, San Dieguito River, San Diego County, California, March 1, 1956."

University of Chicago, Department of Geography, Research Paper No. 70, "Papers on Flood Problems," Gilbert F. White, Editor, 1961.

Additional publications used in preparation of this report are listed in Appendix I.

Area of Investigation

San Diego County is located in the southwestern portion of both the State of California and the United States, as shown on Plate 1, "Boundaries of Investigational Area and Location of Gaging Stations." The county is about rectangular in shape and measures approximately 70 miles from east to west and 60 miles from north to south. The Coast Range traverses the county from northwest to southeast and constitutes a major drainage divide between the arid eastern portion of the county and the coastal region. Approximately two-thirds of the county is situated west of the divide.

Rising from the shores of the Pacific Ocean, the San Diego County Coastal Plain joins the foothill ranges at an average distance from the coast of about 10 miles. Beyond the coastal plain is the foothill valley zone of 10 to 15 miles in width, which has elevations varying from about 600 feet in the valleys to about 1,700 feet at foothill peaks. Farther east, alternating valleys and ranges rise progressively higher, reaching a crest 40 to 60 miles from the coast in the Coast Range. In this mountain-valley zone, elevations range from 3,000 feet to a maximum of about 6,500 feet near the mountain divide.

Seven principal streams originate on the western slope of the Coast Range and discharge into the Pacific Ocean. From north to south these streams are the Santa Margarita, San Luis Rey, San Dieguito, San Diego, Sweetwater, Otay, and Tia Juana Rivers. In the mountain region these streams have cut deep, narrow canyons which occasionally widen into highland valleys. Across the coastal area the major streams traverse valleys which are narrow where the streams have cut through resistant rocks, and wider through the softer formations. The minor streams are less deeply entrenched and have, for the most part, cut only narrow canyons.

This investigation involves portions of five of these principal streams of coastal San Diego County and their floodplain areas. From north to south these streams and the portions for which flood hazard areas have been determined are as follows:

San Luis Rey River from Lake Henshaw to its mouth.

San Dieguito River from Sutherland Dam to its mouth.

San Diego River from El Capitan and San Vicente Dams to Mission Gorge.

Sweetwater River from Sweetwater Dam to its mouth.

Otay River from Lower Otay Dam to its mouth.

There are nine major reservoirs within the five watersheds of San Luis Rey, San Dieguito, San Diego, Sweetwater, and Otay Rivers which were considered in the flood hazard study. More detailed descriptions of the reservoirs are described in the attached appendixes. Table 1 lists the nine major reservoirs along with pertinent data.

TABLE 1

MAJOR RESERVOIRS IN SAN DIEGO COUNTY
CONSIDERED IN FLOOD HAZARD INVESTIGATION

Name of dam	Owner	Stream	Height of dam above original streambed, in feet	Storage capacity, in acre-feet	Area of reservoir*, in acres	Drainage area, in square miles	Use
El Capitan	City of San Diego	San Diego River	217	116,452	1,580	190	Storage of local water for municipal use.
Henshaw	Vista Irrigation Dist.	San Luis Rey River	123	194,323	6,020	205	Storage of local water for irrigation use.
Lake Hodges	City of San Diego	San Dieguito River	131	33,550	1,317	303	Storage of imported and local water for municipal use.
Lake Loveland	California Water & Telephone Company	Sweetwater River	198	27,700	475	98	Storage of local water for municipal, industrial and irrigation use.
San Vicente	City of San Diego	San Vicente Creek	199	90,234	1,069	75	Storage of imported and local water for municipal use.
Savage (Lower Otay Reservoir)	City of San Diego	Otay River	145	56,326	1,132	99	Storage of local and imported water for municipal use.
Sutherland	City of San Diego	Santa Ysabel Creek	162	29,680	550	53	Storage of local water for municipal use.
Sweetwater	California Water & Telephone Company	Sweetwater River	108	27,689	936	182	Storage of local and imported water for municipal, industrial and irrigation use.
Upper Otay	City of San Diego	Proctor Valley Creek	77	2,825	139	13	Storage of local water for domestic and municipal use.

*Area at spillway crest elevation

Sweetwater River near Edgmere Road—1916 Flood

Historical collection, Title Insurance and Trust Company, Union Title Office

CHAPTER II. LAND USE MANAGEMENT AND FLOOD PLANNING ACTIVITIES IN SAN DIEGO COUNTY

The location of urban development on the floodplains of the major rivers of semiarid San Diego County poses a flood threat to life and property. Various federal, state, and local agencies have been active both in the planning of physical works and in management of land use to reduce potential flood damages. This chapter discusses the need for land use management in the area, the State's interest in land use, and some of the planning activities being carried on in the area by various public agencies.

Need for Management of Land Use

Since 1936 the federal government has spent 600 million dollars in California on flood control works. In addition, substantial expenditures by state and local agencies have been made. In spite of this, average annual flood damage is greater today than in 1936.

The population of California is expected to double in the next 15 years. To keep pace with this tremendous increase in population, it is necessary to develop the State's land resources that are subject to recurrent flooding by overflow of streams. For proper development of these floodplains to prevent loss of life and property, disruption of commerce, interruption of transportation and communications, and to prevent further reduction of channel capacities, comprehensive planning and management of these floodplain lands are necessary.

Historical Floods

Coastal San Diego County is subject to sudden and severe floods. From the headwaters to the mouths of the canyons, the streams have steep side slopes and are relatively short. From the steeper canyons to the Pacific Ocean, the streams are flatter as they pass through canyons and traverse broad valleys. These flatter channels have insufficient capacity to carry large floods with the result that streams overflow their banks and inundate the valley plains.

Mean seasonal precipitation for coastal San Diego County ranges from about 10 inches near the coast to about 45 inches in the mountains. In addition to geographic variability, precipitation exhibits great seasonal variability as exemplified by records at San Diego where annual precipitation has ranged from about 3 to more than 27 inches. Storm intensity also varies greatly with a recorded maximum of 11.5 inches in 80 minutes recorded at Campo, near the Mexican border.

Nearly all precipitation occurs during the months of November through April. Most precipitation results from general winter storms that are associated with extratropical cyclones of North Pacific origin. Major storms consist of cyclonic disturbances which may last four days or more and which cause precipitation over large areas. Small amounts of precipitation result from infrequent summer thunderstorms and tropical cyclones. Snow occurs in mountain areas during the winter months, however, snowmelt has little effect on flood peaks.

Historical references to floods in San Diego County began in 1769 with the founding of Mission San Diego de Alcala. Although exact records of flows from the mission's founding through the middle of the nineteenth century are not available, analysis of notes and diaries of the Mission Fathers and early travelers indicates which years exhibited exceptional runoff. Examination of these early records and more reliable later data indicates that there have been at least 25 years in the last 194 during which floods have occurred, and it seems probable that of these floods 6 were of destructive magnitude.

Historic floods of magnitudes undoubtedly capable of major damage included the flood of 1825 which changed the course of the San Diego River from Mission Bay to San Diego Bay, and the flood of 1862 said to have been the largest on the San Diego River within recorded history.

The largest major flood of recent times in San Diego County occurred in 1916. This flood was by far the most destructive of record in the county. There were 23 deaths by drowning, most of which were caused by the flood wave created by the failure of Lower Otay Dam. All important highway and railroad bridges were destroyed or severely damaged, many miles of track and roadbeds were washed out, and for nearly a month all supplies had to be brought into San Diego by ship. The only communication with areas outside the county was by wireless after all telephone and telegraph lines failed.

Almost all water supply systems were damaged, including damage to dams, water mains, pipelines, irrigation ditches, wells and pumps. The greatest damage of this type was the complete destruction of Lower Otay Dam, the partial destruction of Sweetwater Dam, and the damaging of the Dulzura conduit of the City of San Diego.

Aside from the loss of life the greatest form of damage was that resulting from the destruction of farmland improvements. The agricultural bottom land of the Otay River Valley and portions of the Tia Juana, Sweetwater, San Dieguito, and San Luis Rey River Valleys were rendered unfit for cultivation. A total of about 1.5 million dollars in direct damage resulted from the loss of agricultural lands, while all other forms of damage to water supply systems, railroads, highways, public utilities, etc., amount to an additional loss of about 3 million dollars.

Since 1916, the flood of 1927 was the most damaging. Even though no exact flood damage information is available, it is known that damages were much less than those of 1916, due primarily to the fact that this flood was of lesser magnitude than that of 1916.

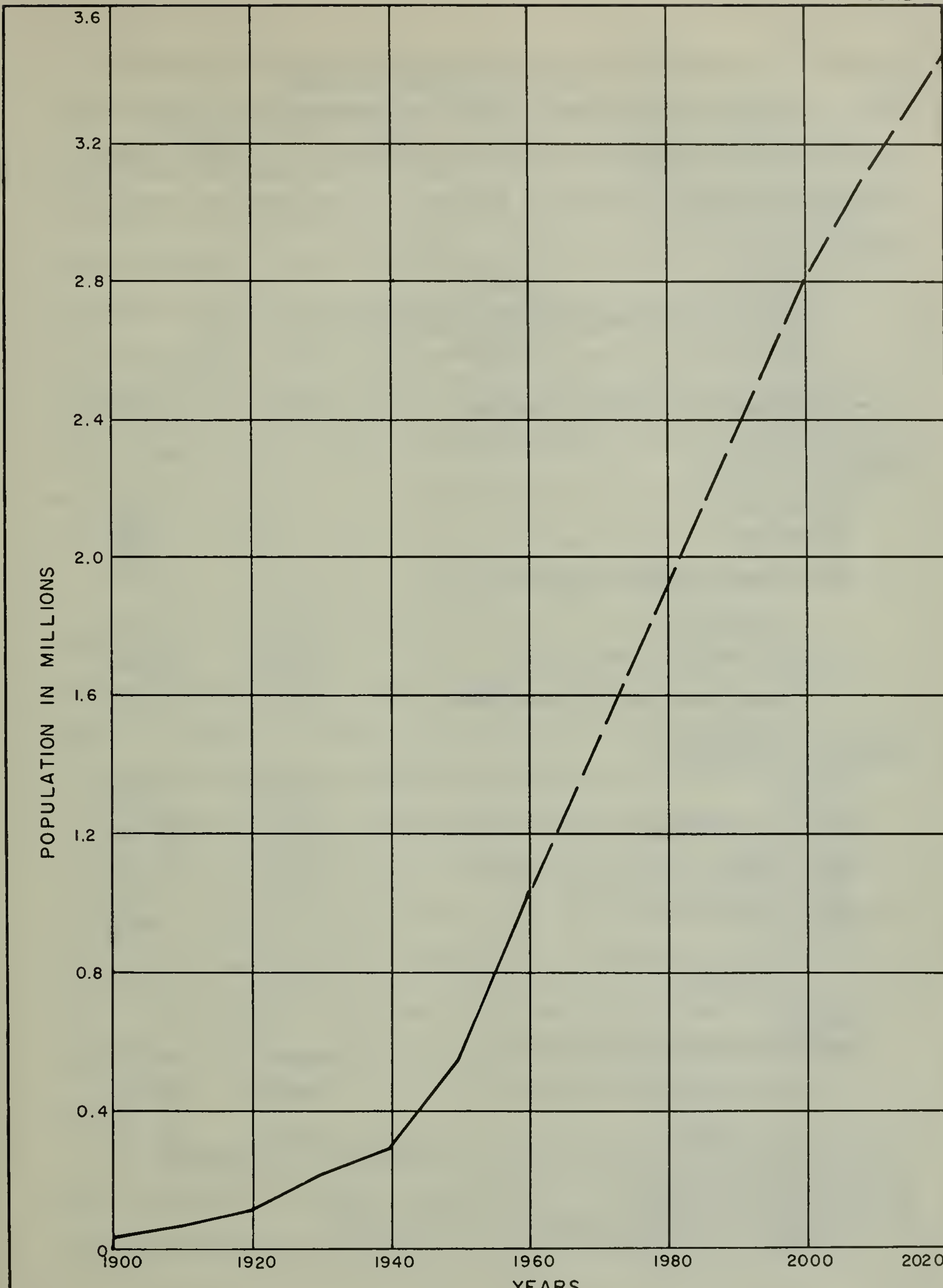
The flood of 1938 was moderately large on streams in the northern portion of the county, but diminished in magnitude in southern areas. Direct losses to agriculture, water supplies, railroads, and highways were estimated to be approximately 600 thousand dollars.

Present and Potential Development

San Diego County is presently experiencing rapid urbanization of its coastal areas. In the period from 1940 to 1960, the population of San Diego County has increased almost 250 percent. In the next two decades, it is estimated that the county's population will about double. Figure 1 depicts the historical and projected population growth of San Diego County from 1900 to 2020.

The total assessed valuation of San Diego County in 1962-63 was $1,727,607,070 compared to $610,188,480 in 1952-53. Based on an assessed valuation of $1,479 per capita in 1962, the assessed valuation of San Diego County in the next two decades will be well over 3 billion dollars. A survey made by the San Diego Manpower Council in cooperation with the California Department of Employment and the U. S. Department of Labor in 1960 indicated that a majority of the projected population growth will be supported by new industries. Land use surveys conducted by the Department of Water Resources show that the gross acreage of urban and suburban

FIGURE 1



HISTORICAL AND PROJECTED POPULATION OF SAN DIEGO COUNTY

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

areas in San Diego County was 51,600 acres in 1948 and 88,350 acres in 1958, an increase of 70 percent. During the same period, irrigated agriculture increased from 58,500 acres to 63,430 acres. Acreages devoted to various categories and classes of land use in these years are presented in Table 2.

TABLE 2

LAND USE IN COASTAL SAN DIEGO COUNTY IN 1948 AND 1958
In acres

Category and class of land use	1948	1958
Urban and Suburban		
Residential	--[a]	40,680
Commercial	--[a]	3,640
Industrial	--[a]	980
Unsegragated urban and suburban area	--[a]	8,260
Subtotals	31,000	53,560
Included nonwater service area	20,600	34,790
Gross urban and suburban area	51,600	88,350
Irrigated Agriculture		
Alfalfa	3,300	2,690
Pasture	4,500	8,530
Citrus and subtropical	30,700	31,480
Truck crops	15,100	11,430
Field crops	1,700	1,030
Deciduous fruits and nuts	3,100	1,800
Small grains	100	5,710
Vineyards	--[b]	760
Subtotals	58,500	63,430
Fallow	--[a]	
Included nonwater service area	5,700	6,030
Gross irrigated agriculture	64,200	69,460
TOTALS	115,800	157,810

a. Value not available
b. Acreage for vineyards grouped with field crops

State Interest in Land Use

As stated, flood damage in California is greater today than in 1936 in spite of expenditures of about 700 million dollars on flood control works by the federal and state governments and substantial amounts by local agencies. This is largely due to encroachment of permanent improvements onto the floodplains without adequate flood control measures being undertaken. Subdivisions, as well as industrial and commercial establishments, are being built in areas which are subject to flooding. A questionnaire survey taken in 1958 and updated in 1960 revealed that only 14 of the 58 counties in California had zoning ordinances controlling development in locations where flood damage was likely to occur.

In view of the persistent trend toward the development of floodplains, further steps are essential to encourage local agencies to control use of floodplains in order to prevent loss of life and minimize damage to property from floods. In order to assist local agencies, the State acts as coordinator between the local agency and the U. S. Army Corps of Engineers in the conduct, by the Corps, of floodplain information studies under Section 206 of the Flood Control Act of 1960. These information studies provide a factual basis in planning the use of floodplains and in preparing zoning ordinances. In addition, the State can assist by making studies and information available to local agencies in support of their zoning activities, such as this report for San Diego County.

Because of the importance of preserving an unobstructed floodway for passage of floodwater, consideration was given by the Flood Plain Zoning Subcommittee of the California Water Commission to an approach under which the State would notify local flood control districts or governmental agencies of the necessity for establishing floodplain prohibitive zones in critical areas. The term "Flood Plain Prohibitive Zone," was defined as that area which, if properly channelized, could discharge flood runoff having a frequency of occurrence of once in 100 years. This approach provided that, if the local authorities failed to act on this request within a reasonable period of years, the State would have the authority to make the necessary investigations and cause such zones to be established. Although it was well recognized that this was, and is, a responsibility primarily of local agencies, such an approach would have enabled the State to exercise some authority in those critical areas in which the local government failed to act.

In a California Water Commission review of the floodplain problem, public hearings were held in both Northern and Southern California to determine the opinions of interested local agencies in regard to state participation in the floodplain zoning program. In general, the local agencies indicated that they were not interested in having the State take a strong position in this field, on the premise that local responsibility would be preempted by the State.

In consideration of the views of local agencies, the Flood Plain Zoning Subcommittee modified its proposed policy on floodplain zoning. The modified policy would give the State, acting through the Department of Water Resources, the responsibility for notifying local governmental agencies of the necessity for establishing Flood Plain Prohibitive Zones on streams on which the State has a financial interest in contemplated or approved federal flood control projects. Under state statutes, the State reimburses local agencies for the cost of acquisition of lands, easements, and rights-of-way, and the cost of relocation of utilities for federally authorized flood control projects. The policy further provides that, where local governmental agencies have failed to inaugurate floodplain zoning, the State shall be relieved of any responsibility for such reimbursement of local costs. It is manifest that development within the floodway will increase the value of rights-of-way required for federal flood control projects and the costs thereof subject to reimbursement by the State. Legislation to implement this policy was introduced in the Legislature during 1963, but was referred to the Senate Fact Finding Committee on Water for further study.

Methods for Obtaining Optimum Land Use

It is generally recognized that at least two measures are required for the optimum use of land subject to overflow from floodwaters.. These are: (1) planning and regulation of land use (or keeping the people and improvements away from the floodwaters); and (2) flood control works (or keeping the floodwaters away from the people and improvements).

Planning and Regulation of Land Use

Offered below in the following paragraphs, for discussion purposes, is information on floodplain planning which could be used as criteria for establishment of zones in which land use regulation could be applied. The suggested criteria are presented for information only.

In the management of floodplain land use, a framework is often needed in which floodplain zones may be defined. An extensive study of guides for setting floodplain regulation lines has been made by the

Department of Geography of the University of Chicago. In Research Paper No. 70, entitled "Papers on Flood Problems," by Professor Gilbert F. White, Editor, criteria are suggested which are susceptible to relatively easy determination and that are readily interpreted to property owners and public officials. The three zones depicted in Figure 2 for various stream cross section conditions have been suggested and are described as follows:

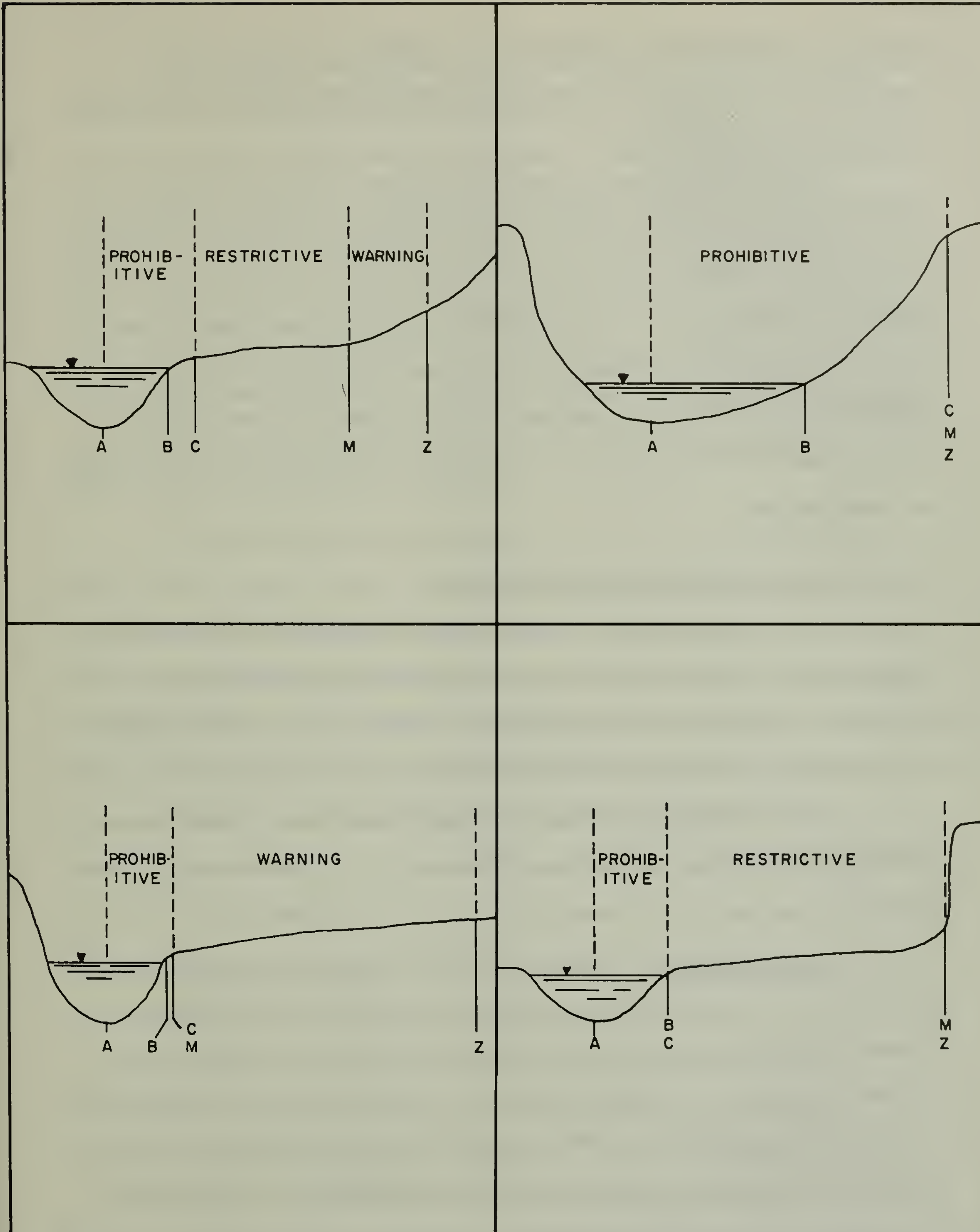
1. Prohibitive Zone - A-C--that zone, in addition to the primary water A-B, where any encroachment would be presumed to be against the public interest. No building would be permitted.

2. Restrictive Zone - C-M--that zone where it would advance the general land-use aims of the community to restrict uses in relation to flood hazard.

3. Warning Zone - M-Z--that zone where it would be in the interest of the property owners, managers, or prospective owners to receive warning of the risks involved but in which restriction is deemed unwarranted. In this zone, flooding would be infrequent and presumably property managers could exercise some degree of self regulation when given advance warning.

Control of land use within the floodplain may be established by zoning, channel encroachment laws, building codes, and acquisition of fee title or flowage easements by public agencies. Often improper land use can be discouraged by keeping the public informed on flood hazards.

If zones are to be established, they should be created after flood hazard areas are mapped and sound criteria are available, both of which must be based on evaluation of hydrologic, hydraulic, and topographic data. These zones are subject to revision as flood control



POSSIBLE FLOOD ZONE SITUATIONS

AFTER FIG. IX-3 IN "PAPERS ON FLOOD PROBLEMS", DEPARTMENT OF GEOGRAPHY, UNIVERSITY OF CHICAGO, RESEARCH PAPER NO. 70, GILBERT F. WHITE, EDITOR, 1961.

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

reservoirs and channels are constructed. Regulation of land use and planning and construction of flood control facilities should be carefully coordinated and integrated.

Floodplain regulation does not preclude the use of land, but merely identifies the type of activities suitable for various areas within the floodplain. Parks, athletic fields, golf courses, fish and wildlife sanctuaries, race tracks, sand and gravel mining, and some types of agricultural and industrial development may often be permitted within areas susceptible to infrequent inundation. Certain commercial and industrial buildings can be "floodproofed," if flooding is considered in their design and construction.

Flood Control Activities in San Diego County

Protecting specific lands from the ravages of floods through construction of flood control works is another method of obtaining optimum land use. Once the land is protected, a higher level of development can occur on the floodplain with attendant enhancement of the economy.

The following describes some of the flood control planning and construction activities of federal, state, and local agencies in San Diego County.

Federal Agencies. Federal agencies active in San Diego County in the field of flood control planning include the U. S. Army Corps of Engineers, the Soil Conservation Service of the U. S. Department of Agriculture, and the U. S. Geological Survey. The latter agency cooperated with the State Department of Water Resources in the preparation of this bulletin by determining areas of potential inundation for floods on the San Dieguito and San Luis Rey Rivers.

The Hodges Flood Control Reservoir Project on the San Dieguito River was authorized for federal participation by Congress in 1958 after a study by the U. S. Army Corps of Engineers. The authorization provided for a federal contribution toward flood control estimated to be $1,961,000 to assist in the financing of enlarging, by local agencies, existing Lake Hodges. The project would consist of a concrete gravity dam approximately 210 feet high above streambed with a crest length of 970 feet. This would provide approximately 375,000 acre-feet of storage, with 280,000 acre-feet for water conservation, 85,000 acre-feet for flood control purposes, and 10,000 acre-feet for sediment storage.

The San Diego River and Mission Bay Project was completed in 1959 by the U. S. Army Corps of Engineers at a total cost of about $12,800,000. Work involved construction of a leveed channel 800 feet wide from 0.4 mile above Morena Boulevard to the ocean. On the San Diego River in Mission Valley, a U. S. Army Corps of Engineers' feasibility report on channel improvements between Morena Boulevard and Fairmount Avenue has been completed by the District Engineer, Los Angeles District, and a public hearing has been held. The total first costs of the project are estimated to be $22,300,000. The plan is scheduled to be considered by the Chief of Engineers, commented upon by the State of California, and submitted to Congress for authorization, probably in 1964.

A report on a flood control survey of the Santa Margarita River, entitled "Report on Survey for Flood Control, Santa Margarita River and Tributaries, California," April 17, 1961, was completed by the U. S. Army Corps of Engineers. The report states that studies completed by the U. S. Army Corps of Engineers in 1949 indicated that the best plan for flood control in the Santa Margarita River watershed would include construction of a multipurpose dam and reservoir on the Santa Margarita River at the De Luz site. The reservoir would have a total capacity of about 210,000 acre-feet for both flood control and water conservation. It would produce an estimated mean seasonal safe yield of 20,000 acre-feet and would reduce the design flood of 55,000 cubic feet per second to 20,000 cubic feet per second. The 1949 studies also concluded that no other flood control improvements in the watershed could be justified. The report also stated that through enactment of Public Law 547, 83rd Congress, the Secretary of the Interior was authorized to construct a multipurpose reservoir at the De Luz site. This legislation also authorized the Secretary of the Army to utilize for purposes of flood control a portion of the capacity of the reservoir. It was concluded in the report that under present conditions of development, flood control improvements upstream from the De Luz site are not economically justified and, therefore, the Chief of Engineers concluded that no additional project be adopted by the United States for flood control on the Santa Margarita River and tributaries.

At the request of the International Boundary and Water Commission, a preliminary plan for flood protection on the Tia Juana River was prepared by the District Engineer, Los Angeles District, U. S. Army Corps of Engineers, to alleviate potential flood problems along the river from the Mexican border to the ocean. The plan would provide for a project consisting of a concrete-lined trapezoidal channel and facilities for off-stream spreading of runoff for ground water recharge. The study was completed and a draft of a report was forwarded in December 1963 to the

United States Section, International Boundary and Water Commission for consideration as an international project.

A report on survey for water resources development on the San Luis Rey River is now in progress by the U. S. Army Corps of Engineers. The survey will involve the feasibility of construction of spreading grounds and multipurpose reservoirs for flood control and water conservation. It is anticipated that the survey will be completed about 1965.

A flood control survey is presently underway by the U. S. Army Corps of Engineers for the portion of the Sweetwater River below Sweetwater Dam. The survey will include determination of the feasibility of construction of channel improvements in this area, which has recently experienced a rapid urbanization. The report on survey is scheduled to be completed in 1965.

A $8,628,000 multipurpose flood control and water storage project on Escondido Creek was authorized in June 1962 under provisions of the Watershed Protection and Flood Prevention Act (Public Law 566). The project would consist of a multipurpose dam and reservoir on Jacks Creek, tributary to Escondido Creek, that would provide flood control and regulation of imported water from the First San Diego Aqueduct, 7.3 miles of improved channel along Escondido and Reidy Creeks, and land treatment measures to provide watershed protection and flood prevention. The plan for the project was prepared by the Escondido Soil Conservation District, City of Escondido, and San Diego County, with assistance from the Division of Soil Conservation and Division of Forestry of the State Department of Natural Resources, and the Soil Conservation Service and the Forest Service of the U. S. Department of Agriculture. Construction is expected to commence in 1964.

Another Public Law 566 development in San Diego County is the Buena Vista Creek Watershed Project. Buena Vista Creek has a watershed of 9,000 acres and discharges into the Pacific Ocean between Oceanside and Carlsbad. The principal community within the watershed is Vista. The project consists of enlarging and concrete-lining the channels to reduce floods and deposition damages. Construction is in progress and should be completed in 1964 at a cost of about $1,860,000.

State Agencies. The need for the State to review and comment on water resource development programs of federal agencies operating in California has long been recognized. This responsibility has been placed upon the State by action of the Congress and accepted and implemented by action and directives of the Legislature and Governor.

With enactment of Public Law 534, the Flood Control Act of 1944, Congress recognized the interests and rights of the states in determining the development and control of water resources. The activity was expanded with the passage of Public Law 566, the Watershed Protection and Flood Prevention Act, and Public Law 685 amending the Flood Control Act of 1948.

In furtherance of this activity, the State attempts to coordinate the planning activities of the various federal and local agencies in order to achieve the most effective and economic development and utilization of the water resources of the State. In its reports reviewing proposed federal flood control projects, the State makes recommendations with respect to such aspects as project engineering and financial feasibility and economic justification. The California Water Plan, together with more detailed studies of units thereof, is utilized as the principal guide.

The Department of Water Resources has been designated by the Governor as the responsible state agency for review and preparation of official state views and recommendations on water projects in, or affecting, the State, proposed by federal agencies or local agencies requesting federal financial assistance, with the exception of those proposed under Public Law 566. The State Soil Conservation Commission is the responsible state agency for projects planned under that law; however, it is the practice of the commission to solicit the views of the Department of Water Resources on such projects.

Official comments of the State include statements of all interested state agencies and often the views of affected cities and counties. To facilitate preparation of official state comments, it has been found desirable for the department to keep informed of flood control planning by federal agencies and furnish, on request, informal comments on preliminary plans prior to completion of final federal feasibility reports.

The department's interest in prospective federal flood control improvements extends beyond the need for coordination of planning activities and includes the department's responsibilities for furnishing assistance in financing costs of lands, easements, and rights-of-way required for federally authorized flood control projects. This assistance program is described in Part 6, Division 6 of the State Water Code and provides for reimbursement of costs of reconstruction of bridges, utilities, and drainage facilities and costs of incidental right-of-way, as well as costs of lands and improvements. In San Diego County, the department has reimbursed the indicated amounts for the following projects:

Project	Federal agency	Costs of lands, easements, and rights-of-way reimbursed by the State As of July 1, 1963	After July 1, 1963*	Total
San Diego River	U. S. Army Corps of Engineers	$2,992,000	$ 0	$2,992,000
Buena Vista Creek Watershed	Soil Conservation Service	48,000	778,000	826,000
Escondido Creek Watershed	Soil Conservation Service	0	2,005,000	2,005,000

*Estimated amount to be reimbursed

After major floods, it has been the custom of the Legislature to make funds available to pay for a portion of the restoration of public property damaged by flood waters. The responsibilities of the Department of Water Resources in assisting public agencies who have suffered property damage are set forth in the Emergency Flood Relief Law, codified in sections 54150 through 54164 of the State Government Code. The general objective of the department's flood damage claim program is to assist stricken public agencies after major floods and, specifically, to determine costs of restoration of damaged public property, distinct from nonreimbursable betterment costs and normal operation and maintenance expense. Review and processing of flood damage claims by the department commenced after the floods of 1938. Additional authorizations were enacted after the floods of 1955-56 and 1958. In 1959, the Emergency Flood Relief Law was enacted by the Legislature.

Local Agencies. Both San Diego County and the City of San Diego have programs of floodplain land use management. Floodplains subject to frequent inundations are zoned for agricultural use, and subdivisions are prohibited. Also, flood-hazard studies are made by the Department of Special Services District of the County of San Diego for all proposed subdivisions. However, no detailed studies had been available for use until this present study of flood hazard areas. Criteria considered by the county are degree of inundation caused by a 50-year flood for subdivisions with a drainage area of less than 10 square miles and a 100-year flood for those with a drainage area of more than 10 square miles. The State Real Estate Commission is then notified of the results of these flood-hazard studies so that the public can be warned of possible flood damage.

Local soil conservation districts, in cooperation with San Diego County or with incorporated cities, cosponsor plans for flood control developed under Public Law 566. Two projects in San Diego County, the Buena Vista Creek Watershed Project and the Escondido Creek Watershed Project, fall into this category.

San Diego River in Mission Valley, downstream from Mission Gorge—1916 Flood

Historical collection, Title Insurance and Trust Company, Union Title Office

CHAPTER III. AREAS OF POTENTIAL INUNDATION

The purpose of this study was to determine the areas of potential flood inundation along portions of the San Luis Rey, San Dieguito, San Diego, Sweetwater, and Otay Rivers for floods of 50- and 100-year recurrence intervals. All of the areas of potential inundation determined for this study are shown on Plate 2. As stated previously, the study consisted of two basic parts--regional hydrology and determination of areas of potential inundation.

The first part of the study, regional hydrology, was reported on in Appendix A to this bulletin. By utilization of graphs in that appendix, peak flood discharges were determined at various points along the streams for floods of 50- and 100-year recurrence intervals.

The second part of the study was the determination of the water-surface profiles for both floods under different assumed conditions of reservoir levels. From the water-surface profiles, areas subjected to possible inundation were determined.

Summaries of the estimated peak flood discharges at selected locations in the San Diego County for two different reservoir conditions are shown in Tables 3 and 4. The locations are shown on plates in the appendixes for each of the rivers. Table 3 shows the estimated 50- and 100-year peak flood discharges with reservoirs assumed full at the beginning of runoff, and Table 4 shows the 50- and 100-year discharges with reservoirs assumed partially full at the beginning of runoff.

The areas of potential flood inundation were delineated on plates at a scale of 1 inch equals 2,000 feet. These plates are included

TABLE 3

ESTIMATED TOTAL PEAK FLOOD DISCHARGES AT SELECTED LOCATIONS IN SAN DIEGO COUNTY, ASSUMING FULL RESERVOIR CONDITIONS

Stream	Location	Peak discharge, in cubic feet per second	
		50-year recurrence interval	100-year recurrence interval
San Diego River	Old Mission Dam	43,000	60,000
	Confluence of San Vicente Creek and San Diego River	36,500	51,000
Sweetwater River	At Highway 101 Bridge	40,000	55,000
	Confluence of Rice Canyon and Sweetwater River	38,300	53,200
Otay River	At San Diego and Eastern R.R. bridge	23,900	33,200
	Stream mile 6.5 from mouth	21,600	29,800
San Dieguito River	At Del Mar	40,100	59,800
	Confluence of Santa Ysabel and Santa Maria Creeks	31,200	45,500
San Luis Rey River	At Oceanside	43,100*	63,000*
	Near Pala	21,700*	31,000*

*Lake Henshaw on the San Luis Rey River was an exception to the general assumption of reservoirs full at beginning of flood runoff. Due to the relatively large storage capacity, it is highly improbable that this facility would ever be full at the time of a major flood. Therefore, the values shown herein for 50- and 100-year peak discharges on the San Luis Rey River are the same as the values in Table 4 for partially full reservoir conditions.

in appendixes to this report for each river system. The areas of inundation shown in this report are based on present conditions of reservoir development and land use. The areas will be modified by artificial

TABLE 4

ESTIMATED TOTAL PEAK FLOOD DISCHARGES AT SELECTED LOCATIONS IN SAN DIEGO COUNTY, ASSUMING PARTIALLY FULL RESERVOIR CONDITIONS*

Stream	Location	Peak discharge, in cubic feet per second: 50-year recurrence interval	Peak discharge, in cubic feet per second: 100-year recurrence interval
San Diego River	Old Mission Dam	18,700	25,500
	Confluence of San Vicente Creek and San Diego River	7,800	10,200
Sweetwater River	At Highway 101 Bridge	23,600	43,250
	Confluence of Rice Canyon and Sweetwater River	22,800	41,500
Otay River	At San Diego and Eastern R.R. bridge	11,500	15,500
	Stream mile 6.5 from mouth	8,050	11,600
San Dieguito River	At Del Mar	25,300	46,200
	Confluence of Santa Ysabel and Santa Maria Creeks	20,500	32,500
San Luis Rey River	At Oceanside	43,100	63,000
	Near Pala	21,700	31,000

*For the San Diego River System, San Vicente Reservoir was assumed to be two-thirds full and El Capitan Reservoir one-half full at beginning of runoff. All other major reservoirs were assumed to be one-half full initially. Lake Henshaw on the San Luis Rey River did not spill for either the 50- or the 100-year flood when assumed to be one-half full initially.

storage and diversions, or by alteration of the floodplains and main channels. The areas will be increased by further encroachment onto the floodplains by commercial, industrial, and residential developments.

Any reduction in flow area by debris, and change in hydraulic properties due to growth of trees and underbrush will also increase the areas of potential inundation. Conversely, any improvements in the hydraulic characteristics of the channels with no further encroachment onto the floodplains will decrease the areas of inundation. These changes in conditions of the river channels are more critical in the wide coastal plains than in the upper portions of the basins. In the former case, flood flows will spread across the floodplains due to insufficient main-channel carrying capacity whereas in the latter case the flood flows will be confined between canyon walls.

The following briefly summarizes for each area studied, the extent of present development within the area and the effect of existing reservoirs on the flood hazards.

San Diego River

A land use survey in the San Diego River Basin downstream from El Capitan and San Vicente Dams to Mission Gorge was conducted by the Department of Water Resources in 1958. The survey indicated that approximately 50 percent of the developed area was devoted to urban use. Most of the urban areas are concentrated around Lakeside and Santee. The results of the 1958 land use survey for the study area are presented in Table 5.

Flood peaks in the San Diego River Basin are attenuated somewhat by temporary storage of water in two existing reservoirs. San Vicente Reservoir (capacity 90,234 acre-feet at spillway elevation) on San Vicente Creek and El Capitan Reservoir (capacity 116,452 acre-feet at spillway elevation) on the San Diego River provide some flood reduction to areas located below. It was found that some attenuation of the flood peak was

TABLE 5

LAND USE IN 1958 IN SAN DIEGO RIVER BASIN
DOWNSTREAM FROM EL CAPITAN AND SAN VICENTE DAMS
TO MISSION GORGE

Category and class of land use	Area: In acres	Area: In percent
Urban and Suburban		
Residential	3,770	
Commercial	370	
Industrial	20	
Unsegregated urban and suburban area	600	
Subtotals	4,760	
Included nonwater service area	2,280	
Gross urban and suburban area	7,040	9.6
Irrigated Agriculture		
Alfalfa	90	
Pasture	1,090	
Citrus and subtropical	1,770	
Truck crops	400	
Field crops	10	
Deciduous fruits and nuts	70	
Small grains	280	
Vineyards	40	
Subtotals	3,750	
Fallow	200	
Included nonwater service area	400	
Gross irrigated agriculture	4,350	6.0
Nonirrigated Agriculture	2,650	3.6
Native Vegetation	7,810	10.7
Unclassified	51,220	70.1
TOTALS	73,070	100.0

achieved even when the reservoirs were assumed to be full at the beginning of runoff due to surcharge storage above the elevations of the spillways. Cuyamaca Reservoir, on Boulder Creek in the extreme upper basin, and other smaller reservoirs in the basin were found to have no appreciable effect on flood peaks in the study area.

The effects of San Vicente and El Capitan Reservoirs on the 50- and 100-year flood peaks were determined by routing these two floods through the reservoirs for two conditions of reservoir levels: (1) both reservoirs full at beginning of runoff; and (2) San Vicente Reservoir two-thirds full and El Capitan Reservoir one-half full at beginning of runoff. The assumption of the two-thirds full condition at San Vicente Reservoir is a different criterion from that assumed for the other major reservoirs in San Diego County. This was because the reservoir provides terminal storage for the First San Diego Aqueduct and a minimum storage of 60,000 acre-feet is maintained for emergency water supply purposes, which amount is approximately two-thirds of the total storage capacity.

Routed reservoir outflows were combined with the natural flood flows from local drainage areas to obtain the total peak discharges. The elevations of the water surface at these points were calculated based upon the total derived peak discharges and the geometry and roughness of the channel and adjacent floodplain areas.

The extent of flooding along the San Diego River and San Vicente Creek from El Capitan and San Vicente Reservoirs to Mission Gorge is shown on Plates C-2A, C-2B, C-2C, C-3A, C-3B, and C-3C, in Appendix C. These plates reflect the areas of potential inundation for 50- and 100-year flood peaks under present conditions for the two assumed initial reservoir conditions.

Sweetwater River

A survey conducted by the Department of Water Resources in 1958 of land use in the Sweetwater River Basin between Sweetwater Dam and the mouth of the river indicated that approximately 9,000 acres, or 72 percent of the total developed area, were devoted to urban use. Most of the urban area was located in the City of Chula Vista. The results of the 1958 land use survey in the Sweetwater River Basin between Sweetwater Dam and the mouth are presented in Table 6.

Peak discharges in the channel of the Sweetwater River below Sweetwater Dam are reduced as a result of temporary storage of water in two existing water conservation reservoirs: Sweetwater Reservoir (capacity 27,689 acre-feet at spillway elevation) and Lake Loveland (capacity 27,700 acre-feet at spillway elevation). The effects of these reservoirs on the 50- and 100-year flood peaks were determined by routing these two floods for two conditions of reservoir levels: (1) reservoirs full at beginning of runoff; and (2) reservoirs filled to one-half capacity at beginning of runoff.

The total peak flood discharges at various points along the river were obtained by combining the routed reservoir outflows with the natural flood flows from local drainage areas below the reservoirs. Water surface elevations in the floodplain were calculated from the total peak flood discharges and the geometry and roughness of the channel and adjacent floodplain areas.

Areas along the Sweetwater River from Sweetwater Dam to the mouth that would be subject to flood hazard are shown on Plates D-2 and

Break in Sweetwater Dam—1916 Flood

Historical collection, Title Insurance and Trust Company, Union Title Office

TABLE 6

LAND USE IN SWEETWATER RIVER BASIN BETWEEN SWEETWATER DAM AND THE MOUTH IN 1958

Category and class of land use	Area	
	In acres	In percent
Urban and Suburban		
Residential	4,240	
Commercial	310	
Industrial	40	
Unsegregated urban and suburban area	470	
Subtotals	5,060	
Included nonwater service area	3,920	
Gross urban and suburban area	8,980	29.0
Irrigated Agriculture		
Alfalfa	0	
Pasture	170	
Citrus and subtropical	820	
Truck crops	990	
Field crops	0	
Deciduous fruits and nuts	--[a]	
Small grains	10	
Vineyards	0	
Subtotals	1,990	
Fallow	610	
Included nonwater service area	590	
Gross irrigated agriculture	3,190	10.3
Nonirrigated Agriculture	320	1.0
Native Vegetation	1,520	4.9
Unclassified	16,990	54.8
TOTALS	31,000	100.0

a. Less than five acres

D-3 Appendix D. The plates reflect the areas of potential inundation for 50- and 100-year flood peaks for the two assumed initial reservoir conditions.

Otay River

About 3,900 acres, or 60 percent, of the approximately 6,500 acres of developed land in the Otay River Basin Below Lower Otay Reservoir were devoted to urban uses in 1958, according to a land use survey conducted by the Department of Water Resources. Most of this urban land is located in the Imperial Beach-Palm City area on the southern edge of San Diego Bay. The results of the 1958 land use survey for the portion of Otay River Basin between the mouth of the river and Lower Otay Reservoir are presented in Table 7.

Upper and Lower Otay Reservoirs reduce peak discharges of floods from the upper Otay River Basin. Lower Otay Reservoir is created by Savage Dam located on the Otay River about 13 miles upstream from the mouth and impounds 56,326 acre-feet of water at spillway elevation. Upper Otay Reservoir on Proctor Valley Creek has a storage capacity of 2,825 acre-feet. The effect of temporary storage of water in these reservoirs on the 50- and 100-year flood peaks was determined by routing these two floods for two conditions of reservoir levels: (1) reservoirs full at beginning of runoff; and (2) reservoirs filled to one-half capacity at beginning of runoff.

The total flood discharges at various points along the Otay River below Savage Dam were obtained by combining the routed reservoir outflows with flood flows from local drainage areas. The water-surface

TABLE 7

LAND USE IN OTAY RIVER BASIN BETWEEN
LOWER OTAY DAM AND THE MOUTH
IN 1958

Category and class of land use	Area: In acres	Area: In percent
Urban and Suburban		
Residential	1,770	
Commercial	180	
Industrial	30	
Unsegregated urban and suburban area	440	
Subtotals	2,420	
Included nonwater service area	1,500	
Gross urban and suburban area	3,920	8.2
Irrigated Agriculture		
Alfalfa	40	
Pasture	90	
Citrus and subtropical	10	
Truck crops	1,070	
Field crops	10	
Deciduous fruits and nuts	0	
Small grains	0	
Vineyards	0	
Subtotals	1,220	
Fallow	720	
Included nonwater service area	370	
Gross irrigated agriculture	2,310	4.9
Nonirrigated Agriculture	330	0.7
Native Vegetation	2,540	5.3
Unclassified	38,490	80.9
TOTALS	47,590	100.0

elevations at these points were calculated from the total peak flood discharges and the geometry and roughness of the river channel.

Potential flood hazard areas along the Otay River from Savage Dam to the mouth of the river are shown on Plates E-2A, E-2B, E-3A, and E-3B in Appendix E. The plates show the areas which would be subject to flooding for floods of 50- and 100-year recurrence intervals under the two assumed initial reservoir conditions.

San Dieguito River

A land use survey in the San Dieguito River Basin from Sutherland Dam to the river mouth, conducted by the Department of Water Resources in 1958, indicated that the major portion of the developed area was devoted to agriculture. Only about 8 percent of the developed area was devoted to urban use. The urban areas were located principally near the ocean in the Del Mar-Solano Beach area and in the town of Ramona in the upper basin. The results of the 1958 land use survey conducted in the San Dieguito River Basin from Sutherland Dam to the mouth of the river are presented in Table 8.

River flows in the San Dieguito River Basin are regulated by Sutherland Reservoir (capacity 29,680 acre-feet at spillway elevation) on Santa Ysabel Creek in the upper basin, and by Lake Hodges (capacity 33,550 acre-feet at spillway elevation) in the lower basin, about 12 miles upstream from the river mouth. The effect of these reservoirs on the 50- and 100-year flood peaks was determined by routing these two floods for two conditions of reservoir levels: (1) reservoirs full at beginning of runoff; and (2) reservoirs filled to one-half capacity at beginning of runoff.

TABLE 8

LAND USE IN SAN DIEGUITO RIVER BASIN BETWEEN
SUTHERLAND DAM AND THE MOUTH
IN 1958

Category and class of land use	Area In acres	Area In percent
Urban and Suburban		
Residential	650	
Commercial	70	
Industrial	10	
Unsegregated urban and suburban area	1,390	
Subtotals	2,120	
Included nonwater service area	1,010	
Gross urban and suburban area	3,130	1.7
Irrigated Agriculture		
Alfalfa	1,310	
Pasture	1,330	
Citrus and subtropical	5,220	
Truck crops	260	
Field crops	360	
Deciduous fruits and nuts	110	
Small grains	530	
Vineyards	20	
Subtotals	9,140	
Fallow	970	
Included nonwater service area	980	
Gross irrigated agriculture	11,090	6.0
Nonirrigated Agriculture	24,380	13.1
Native Vegetation	6,450	3.5
Unclassified	140,410	75.7
TOTALS	185,460	100.0

Routed reservoir outflows were combined with the natural flood flows from local drainage areas to obtain the total peak discharges at various points along the stream. The elevations of the water surface at these points were calculated based upon the total derived peak discharges and the geometry and roughness of the channel and adjacent floodplain areas.

The extent of flooding along the San Dieguito River from Sutherland Dam to the mouth is shown on Plates 4-A through 4-E in Appendix F, which was prepared by the U. S. Geological Survey. These plates reflect the areas of potential inundation for 50- and 100-year flood peaks for the two assumed initial reservoir conditions.

San Luis Rey River

In 1958, a land use survey by the Department of Water Resources in the San Luis Rey River Basin below Lake Henshaw showed there were only about 3,400 acres, or about 10 percent, of the more than 32,000 acres of developed lands that were devoted to urban use. The remaining 90 percent of the developed area was devoted to irrigated and nonirrigated agriculture. Most of the urban lands were located at the mouth of the river near Oceanside. The results of the 1958 land use survey conducted in the San Luis Rey River Basin from the mouth of the river to Henshaw Dam are presented in Table 9.

Flood peaks along the lower San Luis Rey River are affected by Lake Henshaw (capacity 194,323 acre-feet at spillway elevation) which has completely controlled floods from the upper portion of the drainage area since the dam was built in 1922. Studies by the U. S. Geological Survey

TABLE 9

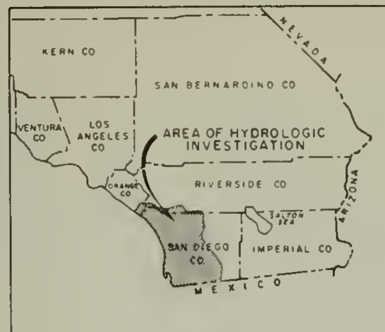
LAND USE IN SAN LUIS REY RIVER BASIN
BETWEEN LAKE HENSHAW AND THE MOUTH
IN 1958

Category and class of land use	Area: In acres	Area: In percent
Urban and Suburban		
Residential	1,440	
Commercial	150	
Industrial	30	
Unsegregated urban and suburban area	900	
Subtotals	2,520	
Included nonwater service area	860	
Gross urban and suburban area	3,380	1.5
Irrigated Agriculture		
Alfalfa	530	
Pasture	2,830	
Citrus and subtropical	11,620	
Truck crops	3,410	
Field crops	470	
Deciduous fruits and nuts	650	
Small grains	1,310	
Vineyards	130	
Subtotals	20,950	
Fallow	710	
Included nonwater service area	1,590	
Gross irrigated agriculture	23,250	10.2
Nonirrigated Agriculture	5,850	2.6
Native Vegetation	17,100	7.5
Unclassified	177,690	78.2
TOTALS	227,270	100.0

indicate that the reservoir would contain the entire 50- or 100-year flood peak assuming the reservoir would be one-half full at the beginning of runoff. The probability that Lake Henshaw would be full at the time of a major flood is so remote that no consideration was given to the magnitude of flood peaks for this condition.

The natural peak discharges for the 50- and 100-year floods in the basin below Henshaw Dam were determined by methods outlined in Appendix A to this bulletin. The water-surface elevations were determined from the peak discharges and the hydraulic characteristics of the river channel under present conditions.

Areas subject to flooding along the San Luis Rey River from Henshaw Dam to the mouth are shown on Plates 5-A through 5-F in Appendix G, which was prepared by the U. S. Geological Survey. The plates reflect the extent of potential inundation for 50- and 100-year flood peaks.



LOCATION MAP

LEGEND

REGIONAL DRAINAGE BOUNDARY

RIVER BASIN OR STREAM GROUP DRAINAGE BOUNDARY

SUBAREA DRAINAGE BOUNDARY

AREAS INVESTIGATED FOR POSSIBLE INUNDATION

▲ STREAM GAGING STATION

UMBER	STREAM GAGING STATION
1	SANTA MARGARITA RIVER AT YSIDORA
2	SANTA YSABEL CREEK AT SUTHERLAND DAM
3	TEMECULA CREEK AT VAIL DAM
4	MURRIETA CREEK AT TEMECULA
5	SAN JUAN CREEK NEAR SAN JUAN CAPISTRANO
6	CAMPO CREEK NEAR CAMPO
7	SANTA MARIA CREEK NEAR RAMONA
8	SWEETWATER RIVER NEAR DESCANSO
9	ARROYO TRABUCO NEAR SAN JUAN CAPISTRANO
10	ALISO CREEK AT EL TORO
11	SAN DIEGUITO RIVER AT HODGES DAM
12	SANTA MARGARITA RIVER NEAR TEMECULA
13	SANTA MARGARITA RIVER NEAR FALLBROOK
14	GUEJITO CREEK NEAR SAN PASQUAL
15	SAN ONOFRE CREEK NEAR SAN ONOFRE
16	SANTA YSABEL CREEK NEAR RAMONA
17	JAMUL CREEK NEAR JAMUL
18	SAN LUIS REY RIVER AT OCEANSIDE
19	SAN LUIS REY RIVER NEAR BONSALL
20	SAN LUIS REY RIVER AT MONSERATE NARROWS
21	SAN DIEGO RIVER NEAR SANTEE

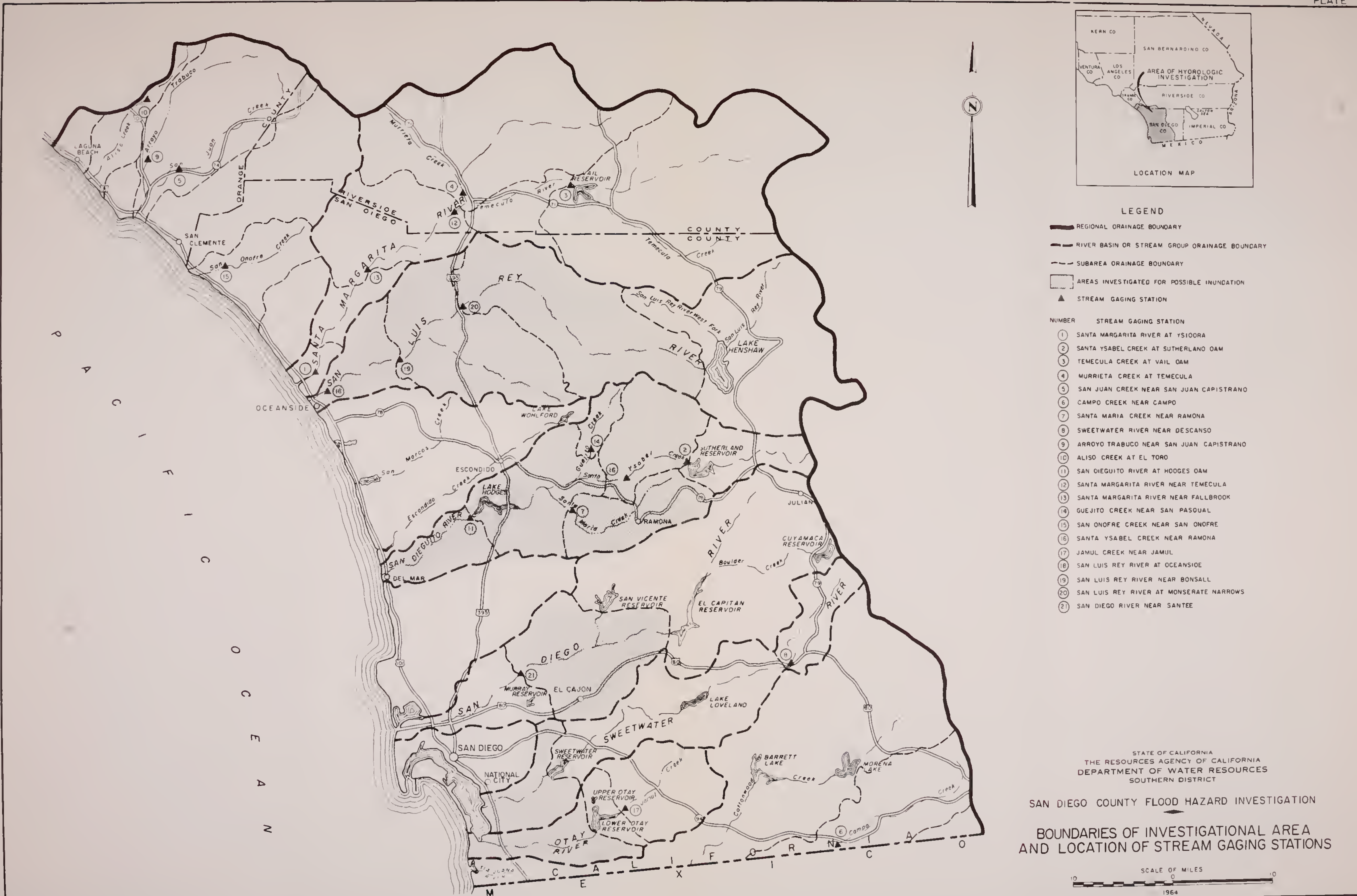
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

DIEGO COUNTY FLOOD HAZARD INVESTIGATION

UNDARIES OF INVESTIGATIONAL AREA
LOCATION OF STREAM GAGING STATIONS

SCALE OF MILES
10 0 10

1964



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

BOUNDARIES OF INVESTIGATIONAL AREA AND LOCATION OF STREAM GAGING STATIONS

1964

LOCATION MAP

LEGEND

REGIONAL DRAINAGE BOUNDARY

RIVER BASIN OR STREAM GROUP DRAINAGE BOUNDARY

SUBAREA DRAINAGE BOUNDARY

AREAS INVESTIGATED FOR POSSIBLE INUNDATION

AREAS OF POTENTIAL INUNDATION FOR 100-YEAR FLOOD WITH RESERVOIRS FULL INITIALLY

STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

SOUTHERN DISTRICT

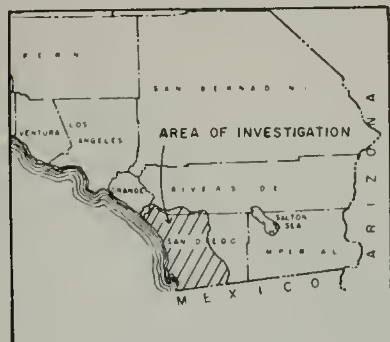
AN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

CATION OF AREAS OF POTENTIAL INUNDATION

SCALE OF MILES

10 0 10

1964



LOCATION MAP

LEGEND

REGIONAL DRAINAGE BOUNDARY

RIVER BASIN OR STREAM GROUP DRAINAGE BOUNDARY

SUBAREA DRAINAGE BOUNDARY

AREAS INVESTIGATED FOR POSSIBLE INUNDATION

AREAS OF POTENTIAL INUNDATION FOR 100-YEAR FLOOD WITH RESERVOIRS FULL INITIALLY

STATE OF CALIFORNIA
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SOUTHERN DISTRICT

AN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

CATION OF AREAS OF POTENTIAL INUNDATION

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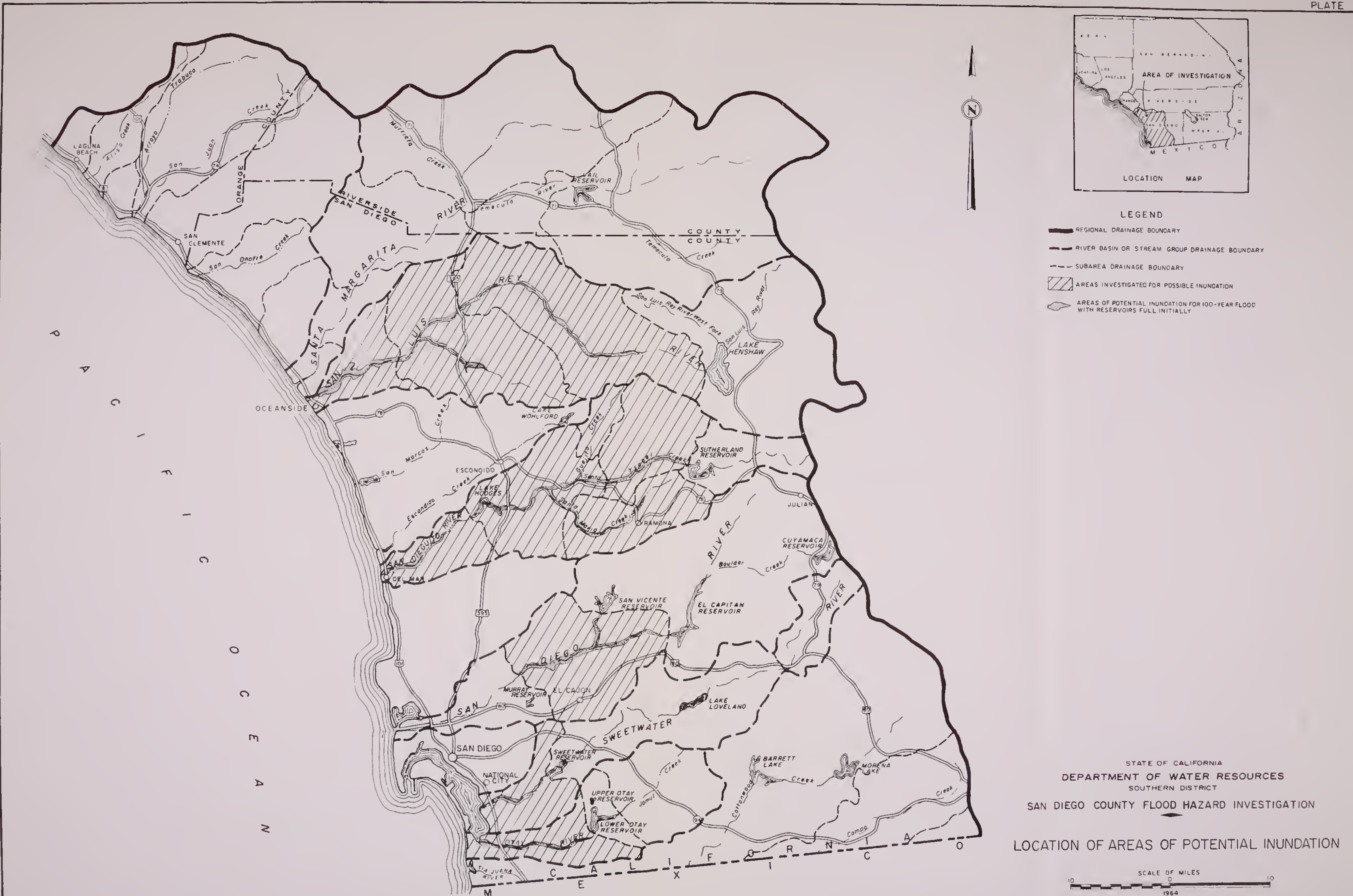
1964

PLATE 2



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

LOCATION OF AREAS OF POTENTIAL INUNDATION

APPENDIX B

METHODS AND PROCEDURES

APPENDIX B

METHODS AND PROCEDURES

APPENDIX B

METHODS AND PROCEDURES

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Introduction

This appendix presents a detailed exposition of the methods and procedures used to determine the areas of potential inundation along portions of the San Luis Rey, San Dieguito, San Diego, Sweetwater, and Otay Rivers for floods of 50- and 100-year recurrence intervals.

The procedure adopted to estimate flood discharges from ungaged areas as presented in Appendix A is discussed along with its application. The method used to develop hydrographs illustrating the time-discharge relationship for discharges at selected locations is described. Also described are the methods used in reservoir and stream routing to determine the attenuating effect of reservoir and channel storage on peak flows. Finally, the procedure employed to determine the water-surface profiles is presented, including determination of the areas of potential inundation.

The methods and procedures used in this investigation were adopted after perusal of engineering texts, reports of the U. S. Geological Survey and U. S. Army Corps of Engineers, and publications of local and state agencies. References reviewed as part of this study are listed in Appendix I.

Determination of Flood Discharges from Ungaged Areas

Reliable estimating of unimpaired flood peaks emanating from ungaged areas within coastal San Diego County has been made possible through use of multiple regression equations displaying the functional relationship of peak discharge to selected drainage basin parameters. These parameters were chosen to reflect the possible hydrometeorological and physiographic differences in the study area. The parameters considered were drainage area, basin shape factor, rainfall intensity, annual basin loss (precipitation less runoff), channel slope, and channel storage factor.

The flood peaks for 50- and 100-year recurrence intervals were determined by using the multiple regression analysis because this resulted in a lower standard error of estimate than would result from use of the index flood method. The standard error of estimate was computed by comparing discharges computed by the multiple regression and index flood methods with measured discharges at gaging stations. The index flood method utilizes a regional frequency curve which is defined by a dimensionless ratio of the mean annual flood to floods of other recurrence intervals. It was found that the ratios of the 100-year flood to the mean annual flood were much larger and of greater variability for the semiarid San Diego County area than for the more humid areas of the United States for which the index flood method was developed. Because of this, a small error in estimating the mean annual flood is magnified when determining floods of other recurrence intervals.

Although no one multiple regression equation proved to be reliable in determining flood peaks of all magnitudes, the relatively simple relationship $Q = aA^{b}Sh^{c}$, where a, b, and c are constants, was found to have a high degree of reliability in estimating flood peaks of 50- and 100-year recurrence intervals. The reliability of this relationship could not be significantly improved by the addition of other basin parameters. In this regard, the complex regression equation $Q = aA^{b}St^{c}L^{d}Sh^{e}$ was compared with the simpler regression equation $Q = aA^{b}Sh^{c}$, and it was found that for the 100-year recurrence interval, use of the more complex regression equation resulted in computed discharges which were on the average within 7 percent of the value obtained using the simple equation.

Because of the small difference in computed discharges between the two regression equations, the simpler form of the equation was chosen for the investigation.

The constants in the simpler equation were derived by assigning known values of Q, A, and Sh in the equation $Q = aA^{b}Sh^{c}$, using measured or computed discharges for 18 specific drainage areas in coastal San Diego County, and computing the constants by simultaneous solution of the 18 equations using a digital computer.

The equations derived for computing discharges at the 50- and 100-year flood levels were:

$$Q_{50} = 1016\ A^{0.59}\ Sh^{-0.44}$$

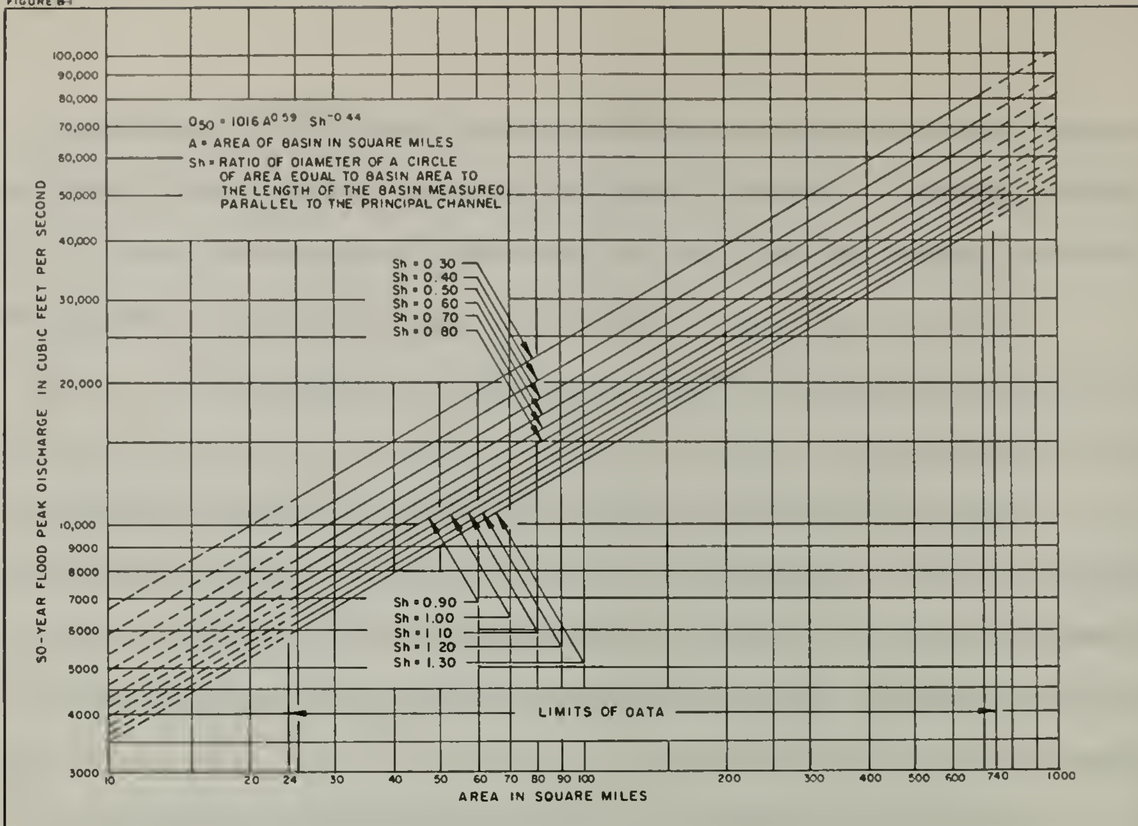
$$Q_{100} = 1288\ A^{0.60}\ Sh^{-0.57}$$

where Q is the flood peak in cubic feet per second, A is drainage basin area in square miles, and Sh is a dimensionless basin shape factor expressed as the ratio of the diameter of a circle of area equal to the basin area to the length of the basin measured parallel to the principal channel.

Peak discharge values can be determined by analytical solution of these equations or through use of the graphical solution of these equations shown in Figures B-1 and B-2.

The investigational areas were divided into subareas corresponding to the major tributaries to the rivers. The peak discharge at selected ungaged points, usually downstream from the confluence of the river and major tributaries, was determined by use of Figures B-1 and B-2 after

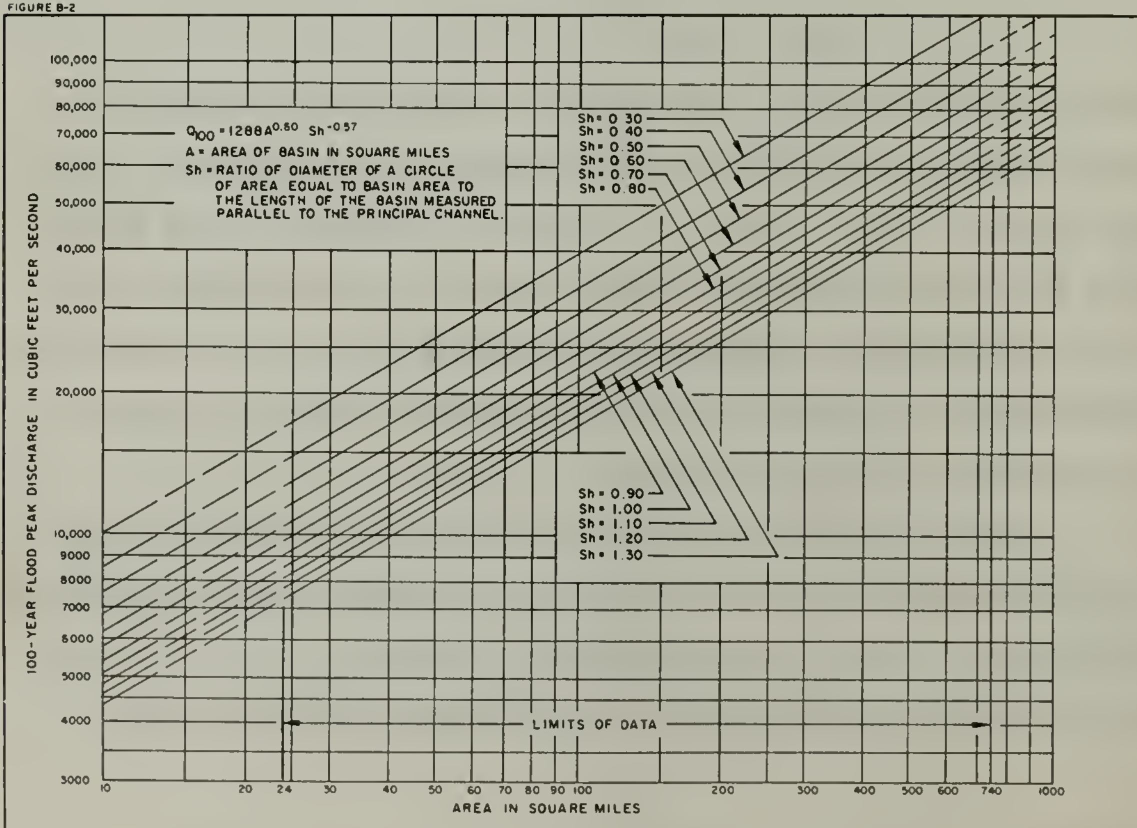
FIGURE B-1



GRAPHICAL SOLUTION OF REGRESSION EQUATION FOR PREDICTING
50-YEAR FLOOD PEAKS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1984

FIGURE B-2



GRAPHICAL SOLUTION OF REGRESSION EQUATION FOR PREDICTING
100-YEAR FLOOD PEAKS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1984

calculating the drainage area and shape factor for the total area upstream or for the tributary area below upstream reservoirs if such reservoirs existed.

A detailed exposition of the multiple regression analysis and the criteria upon which the selection of these two equations are based may be found in "Regional Flood Frequency Analysis," Appendix A to this bulletin, dated March 1963.

Flood Hydrographs

Since peaking time is different for flows originating in different areas, flood hydrographs are necessary for fixing the time of peak flows. A series of hydrographs derived from actual storms for various drainage areas was analyzed to determine the time at which peak flows occur, the width of the hydrograph in hours for various percentages of peak flow, and the length of significant flows. An average hydrograph for coastal San Diego County was then synthesized from the following hydrographs of known storms:

1. Temecula Creek at Pauba Canyon for storms of February 1937 and December 24-25, 1940.
2. Murrieta Creek at Temecula for storms of February 1937, December 24-25, 1940, and January 22-24, 1943.
3. Santa Margarita River below confluence of Murrieta and Temecula Creeks for storms of February 1937, December 24-25, 1940, and January 22-24, 1943.
4. Santa Margarita River near Fallbrook for storms of February 1937, December 24-25, 1940, and January 22-24, 1943.
5. Santa Margarita River at Ysidora for storms of February 1937 and January 22-24, 1943.
6. San Luis Rey River near Bonsall for storms of February 27 to March 6, 1938.
7. San Luis Rey River at Henshaw Dam for storms of January 16-21, 1916, and January 26-30, 1916.

8. Santa Ysabel Creek near Ramona for storm of January 26-29, 1916.

9. Santa Ysabel Creek near Mesa Grande for storm of January 26 to 29, 1916.

10. San Dieguito River near Bernardo for storm of January 26-29, 1916.

11. Sweetwater River at Sweetwater Dam for storm of January 27, 1916.

Table 1 shows the values of percent of peak discharge by hours obtained for an average four-day flood hydrograph for coastal San Diego County. The four-day flood was selected because the 1916 flood, the largest of record, extended over a four-day period and had a recurrence interval of approximately 100 years. Since this study is concerned with 50-and 100-year floods, the four-day flood was selected as the most appropriate for this study.

TABLE 1

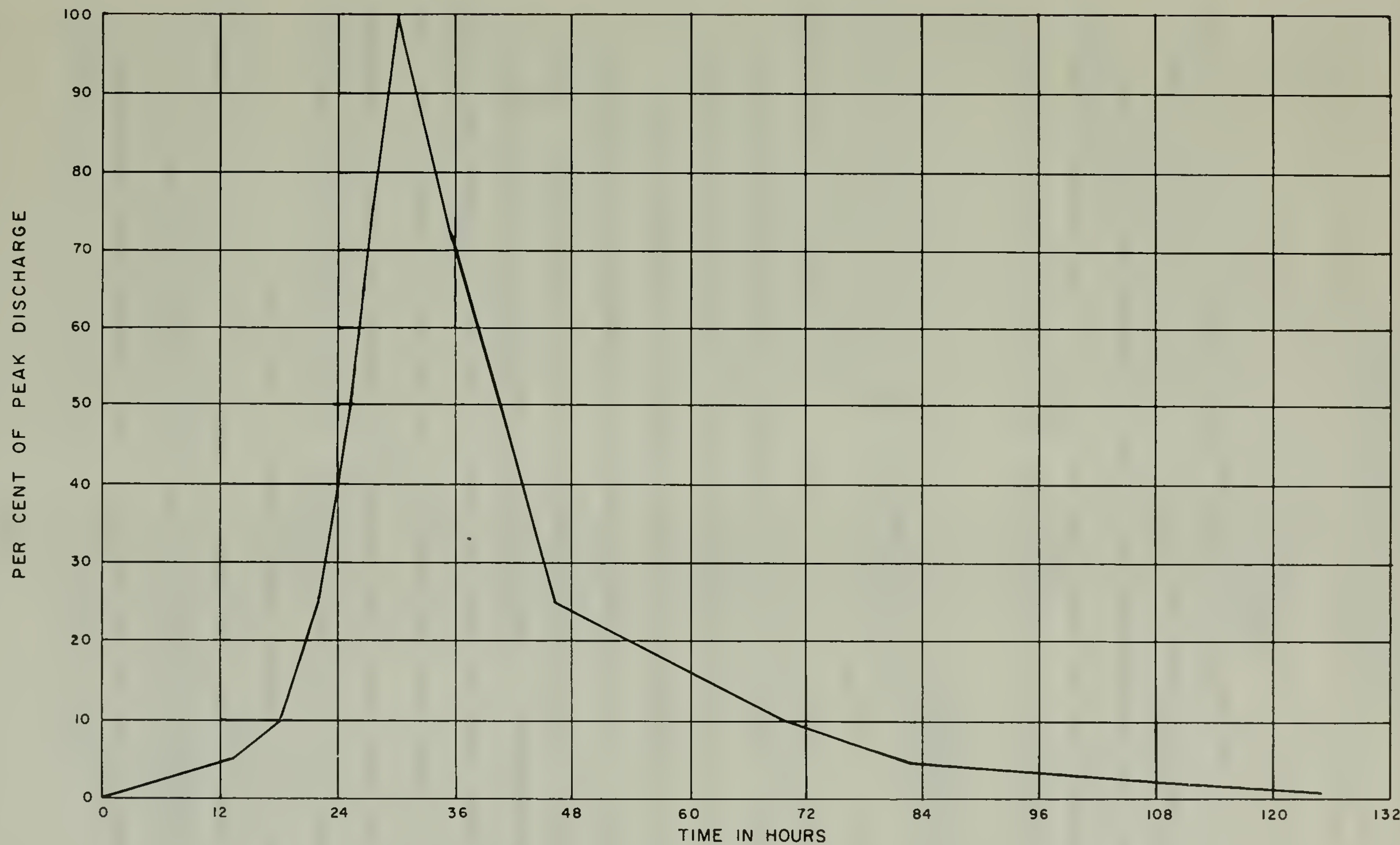
COORDINATES OF AVERAGE FLOOD HYDROGRAPH FOR SAN DIEGO COUNTY

Peak discharge, in percent of maximum	Hours before peak*	Hours after peak*
100	0	0
75	2.8	5.1
50	4.5	11.3
25	7.5	17.0
10	11.7	39.5
5	16.0	53.0

*Peak discharge occurs at the 30th hour.

An average flood hydrograph was plotted from the values in Table 1 and is shown in Figure B-3. Hydrographs for selected locations along the stream channels were calculated by taking the peak discharges at the desired locations and applying the percentage of peak discharge ratios obtained from Figure B-3.

FIGURE B-3



AVERAGE FLOOD HYDROGRAPH FOR SAN DIEGO COUNTY

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

Determination of Peak Flood Flows Affected by Reservoir and Channel Storage

The multiple regression equations give estimates of unimpaired peak flood discharges only and do not reflect any attenuation of flood peaks caused by storage of water in reservoirs and channels. Therefore, peaking time was considered and reservoir flood routing procedures were used to take into consideration the effects of reservoirs on the peak flood discharges from the areas above the reservoirs and natural stream channel routing procedures were used for the areas below these reservoirs.

Reservoir Flood Routing

As stated, flood discharges from drainage areas above reservoirs are attenuated by storage available in the reservoirs, thus decreasing the flood peaks passing the dams. The effects of the reservoirs, except Henshaw and San Vicente, on the 50- and 100-year flood peaks were determined by routing these two floods through the reservoirs with reservoirs one-half full and full at beginning of runoff. Routing was undertaken at San Vicente Reservoir for full and two-thirds full conditions and at Henshaw for one-half full only. In some instances, for assumed reservoir condition of partially-full initially, the peak flood flows at each of the selected points were the result of runoff originating from areas below the dams only. In this case, the overflows from the dam spillways did not contribute to the peak flood flows because the attenuating effect of reservoir storage caused the flood peak to arrive much later. This section describes the reservoir flood routing methods used in this study.

Flood routing techniques are based upon the continuity equation which, when applied to reservoir flood routing, states that the volume of water discharged past the dam during any time interval, must equal the volume of inflow to the reservoir plus or minus the change in storage in the reservoir for the same time interval. The general equation[1/*] is of the form,

$$\text{Outflow} = \text{Inflow} - \frac{\Delta\,\text{Storage}}{\Delta\,\text{Time}} \qquad (1)$$

where the outflow and inflow period is equal to ΔTime.

The general continuity equation[1/*] has been modified to the following form:

$$(I_1 + I_2) + \frac{2S_1}{\Delta t} - O_1 = \frac{2S_2}{\Delta t} + O_2 \qquad (2)$$

where:

I_1 = inflow at the beginning of the routing period

I_2 = inflow at the end of the routing period

Δt = routing period

O_1 = outflow at the beginning of the routing period

O_2 = outflow at the end of the routing period

S_1 = storage at the beginning of the routing period

S_2 = storage at the end of the routing period.

The continuity equation is used in conjunction with the stage-discharge relationship for dam spillways derived for overpour sections from the weir formula:

$$Q = CLH^{3/2} \qquad (3)$$

and for siphon spillways from the formula:

$$Q = CA(2gH)^{1/2} \qquad (4)$$

where:

Q = discharge over spillway or through siphon spillway in cubic feet per second

---

*Numbers refer to reference number in bibliography, Appendix I.

C = empirical discharge coefficient

L = net length of spillway in feet

A = area of siphon at throat in square feet

g = acceleration due to gravity

H = head of water on spillway or total available head in siphon, in feet.

By use of Equations (3) and (4) to obtain the stage-discharge relationship and by use of a storage capacity curve, the reservoir outflow was related directly to the storage in the reservoir above the spillway. This is the storage-outflow relationship. By use of this storage-outflow relationship and the derived inflow hydrograph, Equation (2) was solved for successive increments of time to obtain the outflow hydrograph. A digital computer was used for this portion of the work. A detailed discourse on reservoir flood routing may be found in U. S. Geological Survey Water Supply Paper 1543-B.

Stream Flood Routing

Flows from the reservoirs, as depicted by the outflow hydrographs, were routed downstream and combined with flows as depicted by flood hydrographs for the areas below the dams. In each case, the stream reaches were divided into segments and outflow hydrographs were developed at the end of each of the subdivided reaches, the final ones being at the mouths of the rivers except for San Diego River which was at Mission Gorge.

A simplified form of the Muskingham method[5/] was used in the stream flood routing computations. The general equation is:

$$\text{Storage} = K\left[xI + O(1 - x)\right] \qquad (5)$$

where:

K = slope of storage-weighted discharge relation and has the dimension of time

x = a dimensionless constant which weights the inflow and outflow rates

I = inflow rate at a given time

O = outflow rate at a given time.

By assuming that the storage within a given reach is a function of outflow only, thereby setting x equal to zero, the general equation is reduced to S = KO. Further, by assuming that K is equal to the time, T, required for the center of gravity of the flood wave to pass through the reach, the equation becomes S = TO. From the continuity equation:

$$S_2 - S_1 = \frac{(I_1 + I_2)\Delta t}{2} - \frac{(O_1 + O_2)\Delta t}{2} \qquad (6)$$

substitute TO_1 for S_1 and TO_2 for S_2 and solve for O_2:

$$O_2 = \frac{I_1 + I_2}{\frac{2T}{\Delta t} + 1} + O_1 \frac{\frac{2T}{\Delta t} - 1}{\frac{2T}{\Delta t} + 1} \qquad (7)$$

where:

O_1, O_2 = instantaneous outflow from a reach at the beginning of successive time units Δt

I_1, I_2 = instantaneous inflow to a reach at the beginning of successive time units Δt

T = travel time as defined above

Δt = increment of routing time.

The travel time, T, was determined by estimating the velocity of the flood wave from published data, where possible, but in most cases an average velocity was used as determined from velocities obtained in the backwater computations for various peak discharges.

Channel Hydraulics and Backwater Computations

After the peak flood flows at various points along the rivers were determined, the elevation of the water surface was established by utilization of backwater curve computation methods and stage-discharge curves.

Stream channel characteristics were first determined for the reaches of the rivers under consideration, river flows of varying amounts were routed through the reaches, the stages were determined by backwater computations, and stage-discharge curves were prepared for selection points along the reaches.

Stream Channel Characteristics

The depth of water at any given section along a stream channel for a given quantity of flow depends not only upon the physical characteristics of the channel at that section, but also upon conditions upstream and downstream. Physical characteristics of stream channels that may significantly affect the flow of water, that were evaluated as part of this study, are cross section and roughness. When the physical characteristics of a stream channel have been determined, the "standard step method" of backwater curve computations can be used to compute the water-surface profile.

The physical characteristics of the rivers were determined by field surveys and use of U. S. Geological Survey 7.5 minute quadrangle maps and topographic maps with a scale of 1 inch equals 200 feet and a five-foot contour interval which were obtained from the San Diego County Engineer's office.

Cross Sections. The cross sections of the stream channels and adjacent floodplains were plotted in most cases from the aforecited county maps and from field survey notes supplemented by U. S. Geological Survey quadrangle maps. Detailed cross sections were field surveyed at selected points and used as checks against the topographic maps.

Cross sections used in the backwater computations were taken near abrupt changes in stream channel width and slope, bridges, confluence of tributary streams, changes in general land use and cover, and locations of stream meanders.

Roughness. Stream channel roughness is a major factor that affects the flow of water. Roughness is usually expressed as a coefficient, n, in the Manning formula, as follows:

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2} \qquad (8)$$

where:

Q = channel flow in cubic feet per second

n = Manning's roughness coefficient

A = cross sectional area of water in square feet

R = hydraulic radius of channel in feet

S = slope of energy grade line in feet per foot.

Values of the roughness coefficient in the Manning formula were determined from runoff records, where available, and visual inspection in the field. Photographic slides of the stream channels were taken in the field and compared with slides in the files of the Los Angeles office of the Surface Water Branch, U. S. Geological Survey, for stream channels where the "n" values are known. The U. S. Geological Survey has developed a large file of photographic representations of roughness coefficients for natural stream channels calculated from data obtained at the time of actual floods.

The following factors were considered in evaluating roughness coefficients from photographs: surface roughness, vegetation, channel irregularity, and obstructions.

Backwater Curve Computations

Calculations to establish water-surface profiles for natural stream channels generally involve nonuniform flows, where depth and velocity change between points along the stream. As the surface of a fluid moving in an open channel subjected to changing depths and velocities does not usually change abruptly with the changing conditions of its environment, a "backwater effect" is created. The backwater effect creates a curve in the water surface as the flowing water tries to conform to its constantly changing environment.

The technique used for calculating backwater curves is termed the "standard step method." As the standard step method is a laborious, repetitive process when used in connection with natural stream channels, the procedure is ideally suited for an electronic digital computer. A program for a digital computer was written and used for the backwater curve computations described herein.

The equation for the standard step method of backwater curve computation[5/] and the assumptions accompanying its use are set forth below:

$$WS_1 + \alpha_1 \frac{V_1^2}{2g} + H_f + H_e = WS_2 + \alpha_2 \frac{V_2^2}{2g} \qquad (9)$$

where:

WS_1 and WS_2 = water-surface elevation, in feet, at Sections 1 and 2

$\alpha_1 \frac{V_1^2}{2g}$ and $\alpha_2 \frac{V_2^2}{2g}$ = velocity head, in feet, at Sections 1 and 2

α_1 and α_2 = Coriolis or energy coefficient at Sections 1 and 2

$H_e = 0.5 \Delta \alpha \frac{V^2}{2g}$ = eddy loss, in feet, for decreasing velocity downstream. No loss was assumed for increasing velocity downstream

$\Delta \alpha \frac{V^2}{2g}$ = difference of velocity heads, in feet, between Sections 1 and 2

$H_f = S_f L$ = head loss, in feet due to friction, where S_f is the friction slope, as defined below, and L is the length of reach between Sections 1 and 2.

The friction slope, S_f[5/], is equal to the total discharge, Q, through the reach divided by the geometric mean of the conveyance factors $(K_1K_2)^{1/2}$ for Sections 1 and 2, the quantity squared, as follows:

$$S_f = \frac{Q^2}{K_1K_2} \tag{10}$$

The conveyance factor, K[5/], is defined as:

$$K = \frac{1.486}{n} AR^{2/3} \tag{11}$$

from the Manning formula

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2} \tag{9}$$

or

$$Q = K S^{1/2} \tag{12}$$

In order to take into consideration the nonuniform distribution of velocities in a river section[5/], the velocity head determined from the mean velocity was corrected by multiplying by the energy coefficient, α.

The energy coefficient was determined as described below:

Let ΔA = an incremental area of the entire cross-sectional area, A

w = unit weight of water

v = velocity of water passing the incremental area, ΔA

$\frac{wv^3 \Delta A}{2g}$ = kinetic energy of water passing ΔA per unit time

$\sum \frac{wv^3 \Delta A}{2g}$ = total kinetic energy of water passing cross section

A = total area of cross section

Q = total flow passing cross section

V = mean velocity = $\frac{Q}{A}$

$\alpha \frac{V}{2g}$ = corrected velocity head for the entire area

$\alpha \frac{wV^3 A}{2g}$ =total kinetic energy

Then equating $\sum \frac{wv^3 \Delta A}{2g} = \alpha \frac{wV^3\ A}{2g}$ and solving for α,

$$\alpha = \frac{\int v^3\ dA}{V^3 A} \approx \sum \frac{v^3 \Delta A}{V^3 A} \qquad (13)$$

Calculation of the energy coefficient, α, was included in the computer program as a part of the backwater curve computations.

Special Conditions in Backwater Computations

The digital computer program used to facilitate computations operated only where the flow was subcritical, therefore, special consideration was given to reaches of stream channel where supercritical flows were observed. Special consideration was also given to the backwater effect at the confluence of the rivers with major tributaries and the effect caused by bridges.

In using the computer for computations of backwater upstream from bridges the calculations were first carried past the bridge sections by substituting a section corresponding to the stream before the bridge was constructed. This established a theoretical normal water surface at the bridge section. Backwater effect due to the bridge construction was then computed manually following procedures developed by the U. S. Geological Survey and discussed in U. S. Geological Survey references listed in Appendix I. The original backwater computation was then adjusted by computing the backwater curve upstream starting from the water-surface elevation on the upstream side of the bridge until the water-surface elevation of the adjusted backwater curve coincided with the original theoretical water-surface elevation.

At major tributaries the elevations of the water surfaces immediately upstream from the confluence in both the main river and its tributary were determined by using a variation of the equation for the standard step method of backwater curve computation[5/], Equation (9), as follows:

$$WS_1 + \alpha_1 \frac{V_1^2}{2g} + (S_f L)_{1-2} + 0.5 \left(\frac{\Delta \alpha V^2}{2g}\right)_{1-2} = WS_2 + \alpha_2 \frac{V_2^2}{2g} \quad (14)$$

for the main stream and

$$WS_1 + \alpha_1 \frac{V_1^2}{2g} + (S_f L)_{1-3} + 0.5 \left(\frac{\Delta \alpha V^2}{2g}\right)_{1-3} = WS_3 + \alpha_3 \frac{V_3^2}{2g} \quad (15)$$

for the tributary. Subscript 1 denotes the section immediately below the confluence; subscript 2 denotes the section of the main stream immediately above the confluence; and subscript 3 denotes the section of the tributary immediately above the confluence. The other terms are as defined before. The friction slope, S_f, was assumed to be the arithmetic mean of the friction slope of the respective sections. The backwater computation was then carried upstream past the tributary confluence by first establishing the water-surface elevations immediately upstream from the confluence by a trial and error procedure and then continuing the backwater computations.

In most reaches of the streams where the flow was supercritical, the depth of flow was approximately critical depth, and no attempt was made to locate the point of transition from supercritical to subcritical flows, or to refine the backwater computation to reflect supercritical flow conditions. However, in certain instances, especially in the upper reaches of the river where the bed slopes were steeper than the critical slopes, normal depths were assumed for these reaches.

Stage-Discharge Curves

Backwater curves were computed for various discharges covering a range which included the 50- and 100-year floods for each river under investigation and stage-discharge curves were plotted at selected points. These curves were then used to determine the stages at selected points for the computed peak discharges.

Determination of Areas of Potential Inundation

Areas of potential inundation were determined for the study area for floods of 50- and 100-year recurrence intervals for two assumed reservoir conditions: (a) partially full initially and (b) full, initially.

The water-surface profiles for both the 50- and 100-year floods were determined by first calculating the peak discharges at selected points along the river for the respective floods for the two different assumed initial reservoir conditions. From the known peak discharges and the stage-discharge curves for particular points on the stream, the water-surface elevations were determined and the water-surface profile drawn. A straight line variation in the water-surface profile was assumed between any two successive sections where the stage-discharge relationship was derived.

From the water-surface profiles, the elevations of the flood-waters at any point along the river could be ascertained. Areas which would be subject to inundation from the two floods studied were then delineated upon topographic maps at a scale of 1 inch equals 200 feet. For the purposes of presentation in this report, the areas of potential inundation were delineated on plates at a scale of 1 inch equals 2,000 feet.

APPENDIX C

SAN DIEGO RIVER - AREAS OF POTENTIAL INUNDATION

APPENDIX C

SAN DIEGO RIVER-
AREAS OF POTENTIAL INUNDATION

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(Plates follow text of Appendix)

CHAPTER I. INTRODUCTION

In this appendix are presented magnitudes of peak flood flows at selected locations along the San Diego River for floods of 50- and 100-year recurrence intervals. Areas inundated from these floods are shown on plates at the end of the appendix.

The methodology utilized in this appendix for reservoir and stream channel flood routing and for backwater computations follows commonly used techniques as detailed in Appendix B. Water-surface profiles thus determined were plotted on maps to indicate the areas of potential inundation.

Scope of Investigation

The studies of the flood potential of the San Diego River were directed toward producing reliable estimates of water-surface profiles for flood peaks of 50- and 100-year recurrence intervals and to delineate the areas which might be inundated by these floods. The work necessary to accomplish these objectives consisted of establishing reliable estimates of peak flood flows, determining hydraulic properties of the flood channels, calculating water-surface profiles along the approximately 19 miles of floodplain from Mission Gorge to San Vicente and El Capitan Reservoirs, and delineating areas of potential inundation.

Description of Area of Investigation

The San Diego River watershed has an area of 434 square miles and lies on the western slopes of the Coast Range in San Diego County. The 50-mile long river flows generally southwesterly and discharges into the Pacific Ocean through Mission Bay.

TABLE 1

RESERVOIRS WITHIN THE SAN DIEGO RIVER WATERSHED*

Name of dam	Owner	Stream	Height of dam above original streambed, in feet	Storage capacity, in acre-feet	Area of reservoir, in acres**	Drainage area, in square miles	Use
Chet Harritt	Helix Irrigation District	Quail Canyon Creek	184	10,500	181	1.7	Storage of local and imported water for municipal use.
Cuyamaca	Helix Irrigation District	Boulder Creek	40	11,600	930	12	Storage of local water for irrigation and domestic use.
El Capitan	City of San Diego	San Diego River	217	116,452	1,580	190	Storage of local water for municipal use.
Murray	City of San Diego	Chapparel Canyon	107	6,085	200	3.7	Storage of local and imported water for municipal use.
San Vicente	City of San Diego	San Vicente Creek	199	90,234	1,069	75	Storage of imported and local water for municipal use.

*Data from Department of Water Resources Bulletin No. 17, "Dams Within Jurisdiction of the State of California."

**Area at spillway crest elevation

The San Diego River Basin comprises rugged mountain peaks at higher elevations, but the lower portion of the basin consists of mesa lands and valleys. Elevations throughout the basin generally range from sea level to 600 feet in the lower portion and from 600 to 6,500 feet in the mountains. Cuyamaca Peak, the highest point in the basin, has an elevation of 6,515 feet.

The mean annual precipitation varies from approximately 11 inches in the lower portions to approximately 35 inches in the mountains. The flow at the mouth of the river varies from no discharge to a maximum estimated value of 75,000 cubic feet per second, which occurred in 1916.

There are two major reservoirs, El Capitan and San Vicente Reservoirs, within the San Diego River watershed. San Vicente Reservoir, with a capacity of 90,234 acre-feet, is located on San Vicente Creek, a tributary to San Diego River. The reservoir is used to store imported water from the First San Diego Aqueduct and local runoff transferred from Sutherland Reservoir on Santa Ysabel Creek, tributary to the San Dieguito River. El Capitan Reservoir on the San Diego River, with a capacity of 116,452 acre-feet, impounds local runoff. Both reservoirs are owned and operated by the City of San Diego to meet municipal water demands.

The reservoirs within the San Diego River watershed are listed in Table 1, along with pertinent data.

That portion of the San Diego River Basin considered for potential flood hazards is located between Mission Gorge and El Capitan and San Vicente Dams. The communities of El Cajon, Santee, and Lakeside lie within the study area. The San Diego River Basin and the area within the basin studied for possible inundation are delineated on Plate C-1, "Boundaries of Investigational Area within San Diego River Basin."

CHAPTER II. PEAK FLOOD FLOWS

Determination of peak flood flows at the 50- and 100-year frequency level for ungaged reaches of the San Diego River and its tributaries is discussed in this chapter. The method outlined herein combines the use of regression equations and techniques of reservoir and river channel flood routing. The development of the equations was discussed in detail in Appendix A, "Regional Flood Frequency Analysis," and the routing techniques utilized are explained in Appendix B, "Methods and Procedures."

Determination of Flood Discharges from Ungaged Areas

The estimated peak discharges at selected ungaged points on the San Diego River as a result of runoff emanating from areas below El Capitan and San Vicente Dams for floods of 50- and 100-year recurrence intervals are presented in Table 2. These values of discharge were determined by use of Figures B-1 and B-2 in Appendix B.

The estimated unimpaired peak flood discharges from areas above El Capitan and San Vicente Reservoirs were determined in the same manner as for the areas below the reservoirs. The estimated 50- and 100-year flood peaks for the 190-square-mile drainage area above El Capitan Reservoir were found to be 24,300 and 32,500 cubic feet per second, respectively. The estimated 50- and 100-year flood peaks for the 75-square-mile drainage area above San Vicente Reservoir were found to be 15,000 and 20,500 cubic feet per second, respectively.

The shape of the flood hydrograph characterized by these peaks is shown on Figure B-3 and is discussed further in Appendix B.

TABLE 2

ESTIMATED PEAK FLOOD DISCHARGES FROM AREAS BELOW EL CAPITAN AND SAN VICENTE RESERVOIRS FOR SELECTED LOCATIONS ON THE SAN DIEGO RIVER

Location	Drainage area, in square miles	Diameter of circle of equivalent area, in miles	Basin length, in miles	Shape factor Sh	Peak discharge, in cubic feet per second: 50-year flood	Peak discharge, in cubic feet per second: 100-year flood
Old Mission Dam	114.3[a]	12.1	15.6	0.75	18,700	25,500
Approx. 0.7 mile downstream from Sycamore Canyon	99.6[a]	11.3	12.8	0.88	16,200	21,500
Confluence of Forester Creek and San Diego River	81.4[a]	10.2	12.3	0.83	14,700	19,500
Approx. 0.5 mile downstream from Santee	58.1[a]	8.6	10.9	0.79	12,300	16,500
Cottonwood Road	52.9[a]	8.2	8.9	0.92	10,800	14,300
Approx. 0.8 mile downstream from Lakeside	44.7[a]	7.5	7.9	0.96	9,700	12,700
Confluence of San Vicente Creek San Diego River	29.4[a]	6.1	6.9	0.89	7,800	10,200
Confluence of Wildcat Canyon and San Diego River	20.4[b]	5.1	6.2	0.82	6,600	8,700
Approx. 2 miles downstream from El Monte Park	10.0[b]	3.6	3.0	1.19	3,600	4,600

a. Excludes 190.0 square miles of drainage area above El Capitan Dam and 75.0 square miles of drainage area above San Vicente Dam

b. Excludes 190.0 square miles of drainage area above El Capitan Dam

The flood peaks obtained from Figures B-1 and B-2 of Appendix B are attenuated by storage capacity available in the reservoirs, as well as channel storage, and the resulting diminished outflows were combined with the values shown in Table 2 to determine the total discharge at various points.

Effect of Reservoirs and Channel Storage on Peak Flood Flows

This section shows the attenuating effect of reservoir and channel storage on peak flood flows. The diminishing of flood peaks, as a result of flood flows entering reservoir storage will be discussed first, followed by a description of the effect of channels on flood peaks.

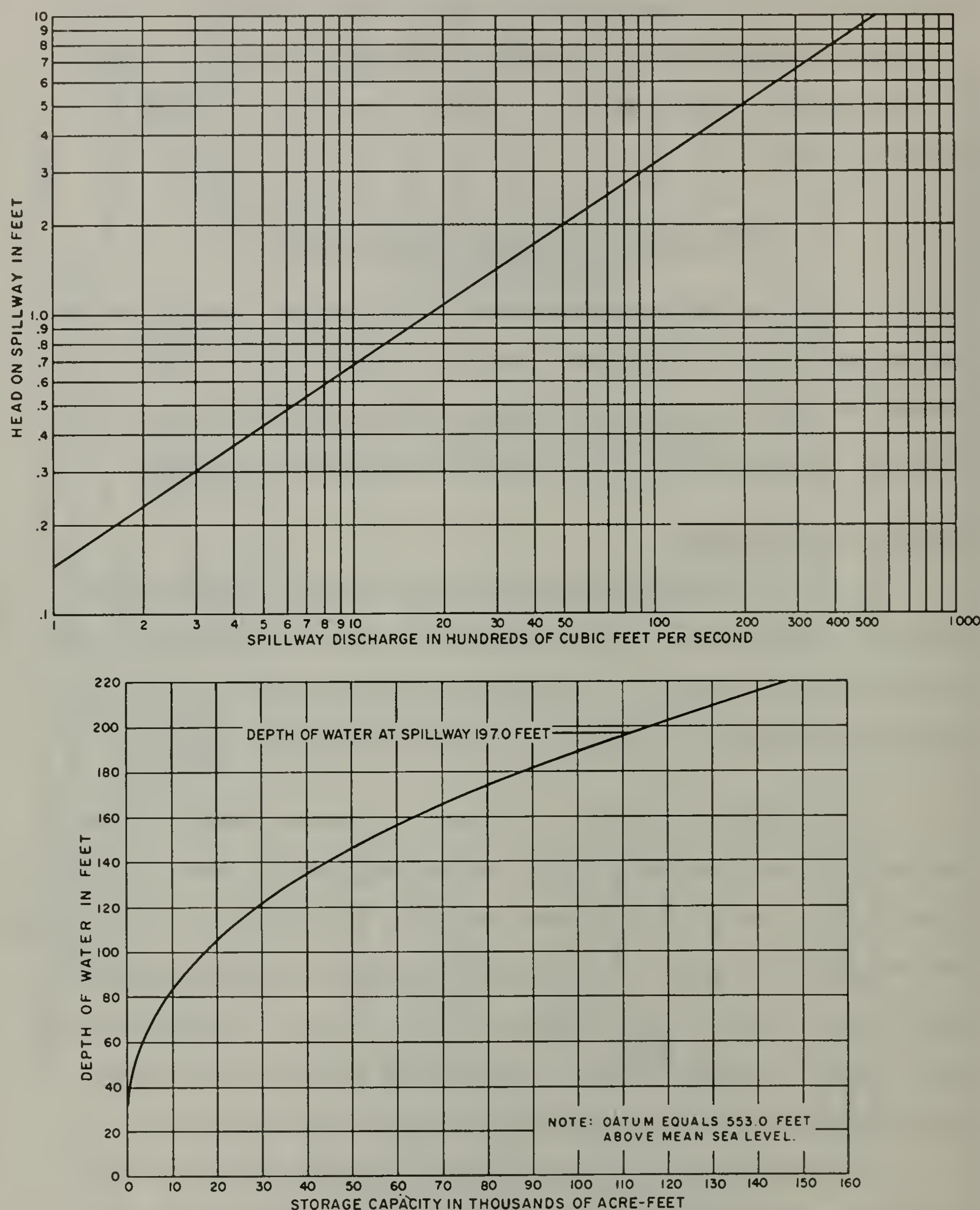
Reservoir Flood Routing

The 50- and 100-year floods upstream from El Capitan and San Vicente Reservoirs were routed through these reservoirs assuming two initial reservoir conditions: (1) El Capitan Reservoir one-half full and San Vicente Reservoir two-thirds full; and (2) both reservoirs full.

El Capitan Reservoir. Utilizing the storage capacity curve and the spillway discharge curve for El Capitan Reservoir as shown on Figure C-1, flood flows at the 50- and 100-year recurrence intervals were routed through the reservoir. As stated, this was done assuming two initial reservoir conditions: one-half full (58,226 acre-feet) and full (116,452 acre-feet). The results of routing the flood flows for the different conditions of initial reservoir storage are depicted graphically on Figure C-2.

With the reservoir full initially, the flood peaks for the inflow and outflow hydrographs at the 100-year recurrence intervals are

FIGURE C-1



SPILLWAY DISCHARGE AND STORAGE CAPACITY CURVES FOR EL CAPITAN RESERVOIR

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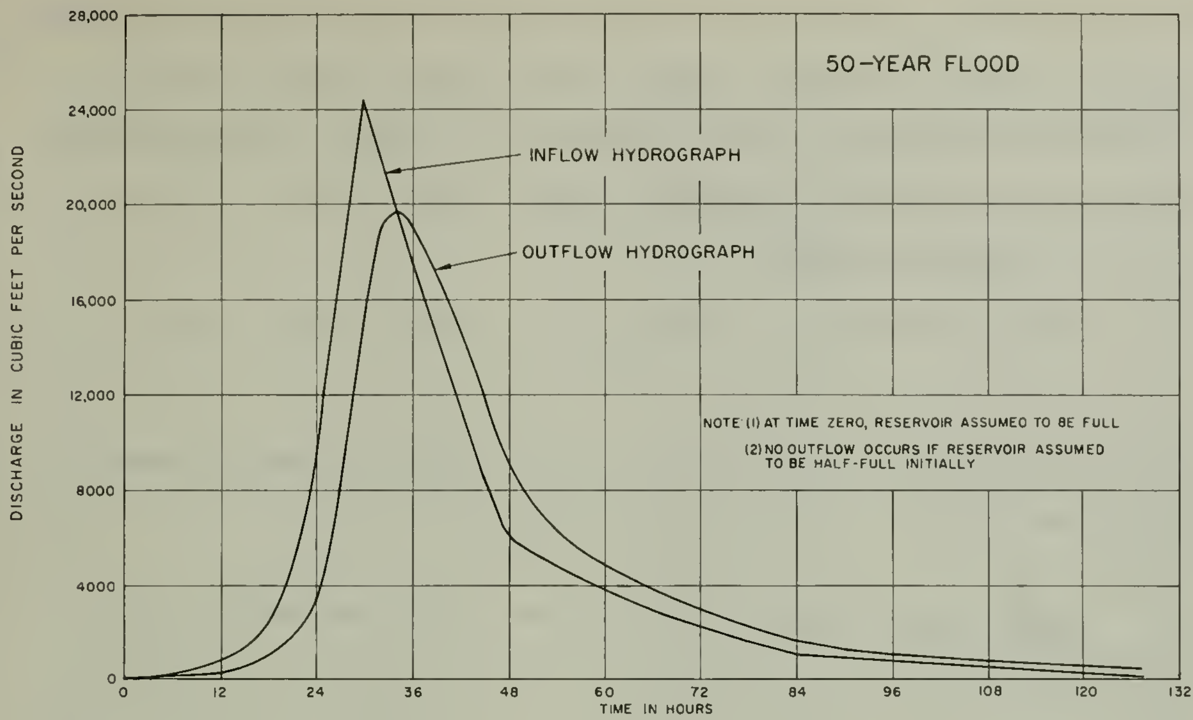

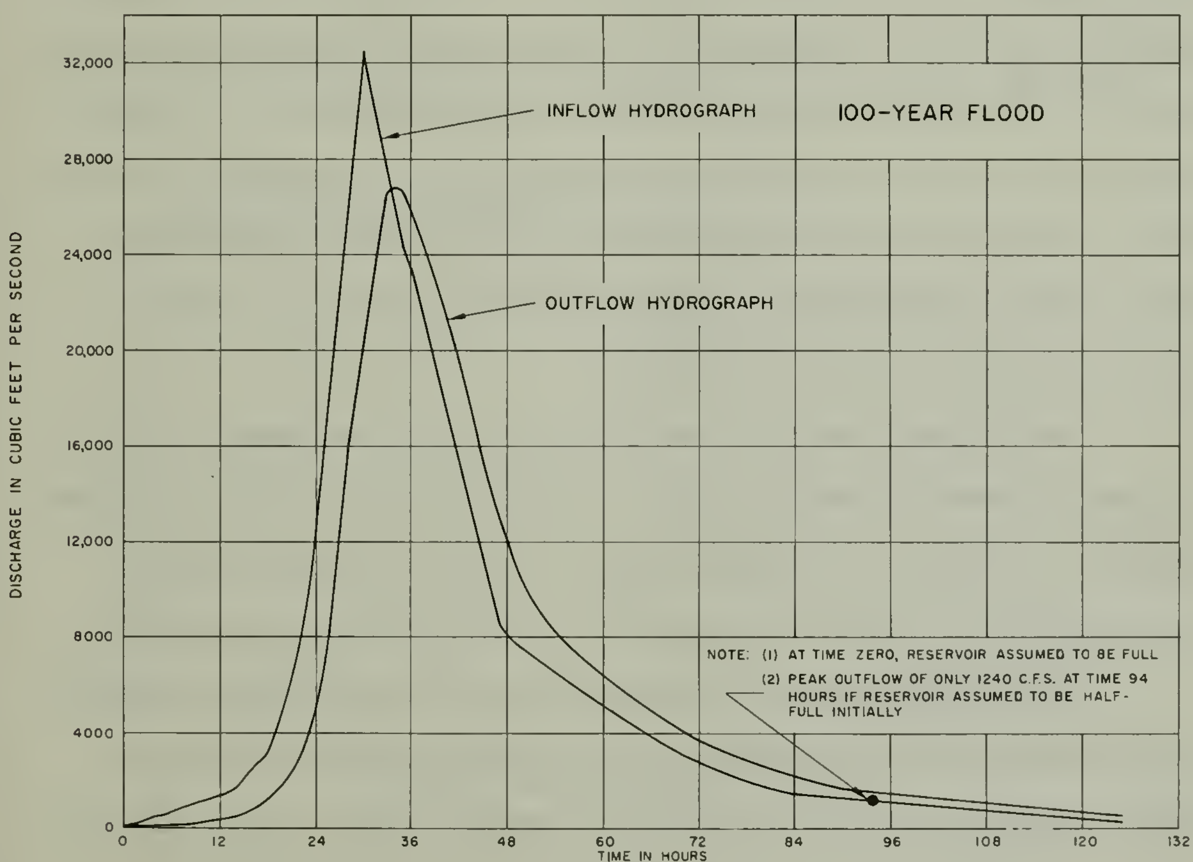

INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT EL CAPITAN RESERVOIR

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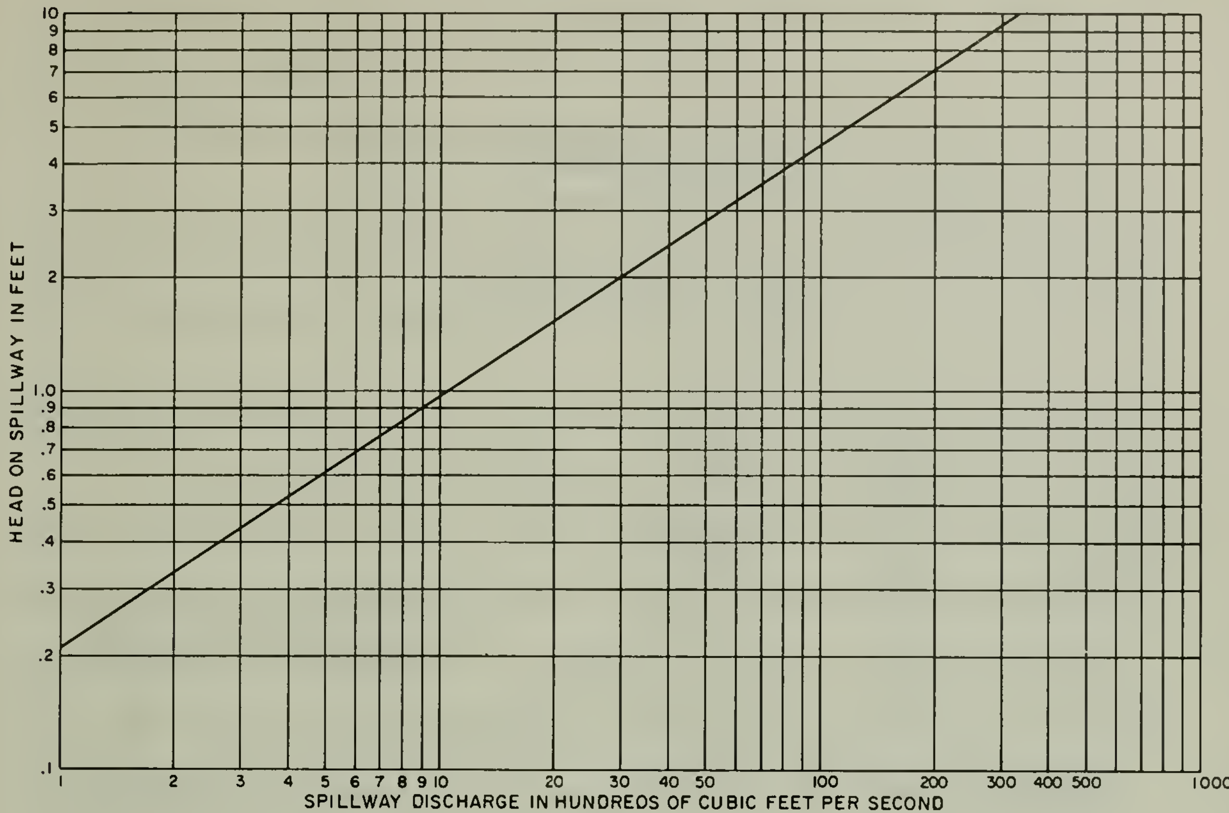
32,500 and 26,800 cubic feet per second, respectively, with a lag of about four hours between the peaks. At the 50-year flood recurrence interval, the flood peaks are approximately 24,300 and 19,600 cubic feet per second for the inflow and outflow hydrographs, respectively, with a lag of about four hours between the peaks.

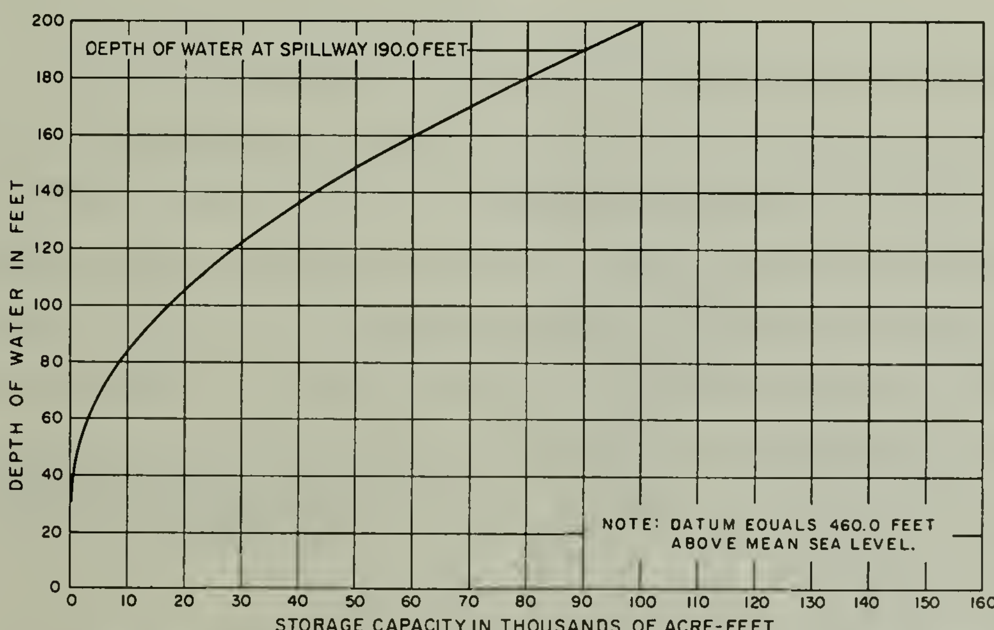
When the reservoir is assumed to be one-half full initially, the peak outflow at the 100-year recurrence interval was only 1,240 cubic feet per second, with a lag of about 64 hours between hydrograph peaks. For a 50-year flood, no reservoir spill occurred.

San Vicente Reservoir. Because San Vicente Reservoir is used to store imported water, it is improbable that the amount of storage would ever decrease to a one-half full condition as is the case with El Capitan Reservoir. The City of San Diego has indicated that the future operating procedure is based on maintaining a minimum storage of 60,000 acre-feet of water in San Vicente Reservoir for emergency use. Therefore, the flood routing calculations for this reservoir were based on the assumption of initial reservoir conditions of approximately two-thirds full (60,000 acre-feet) and full (90,234 acre-feet).

The storage capacity curve and the spillway discharge curve for San Vicente Reservoir shown on Figure C-3 were utilized in the routing computations. The result of routing floods of 50-and 100-year recurrence intervals with the reservoir initially full are depicted on Figure C-4.

The 100-year flood, with the reservoir initially full, produced inflow and outflow peak discharges of 20,500 and 16,400 cubic feet per second, respectively, with four hours lag between peaks. For the 50-year





SPILLWAY DISCHARGE AND STORAGE CAPACITY CURVES FOR SAN VICENTE RESERVOIR

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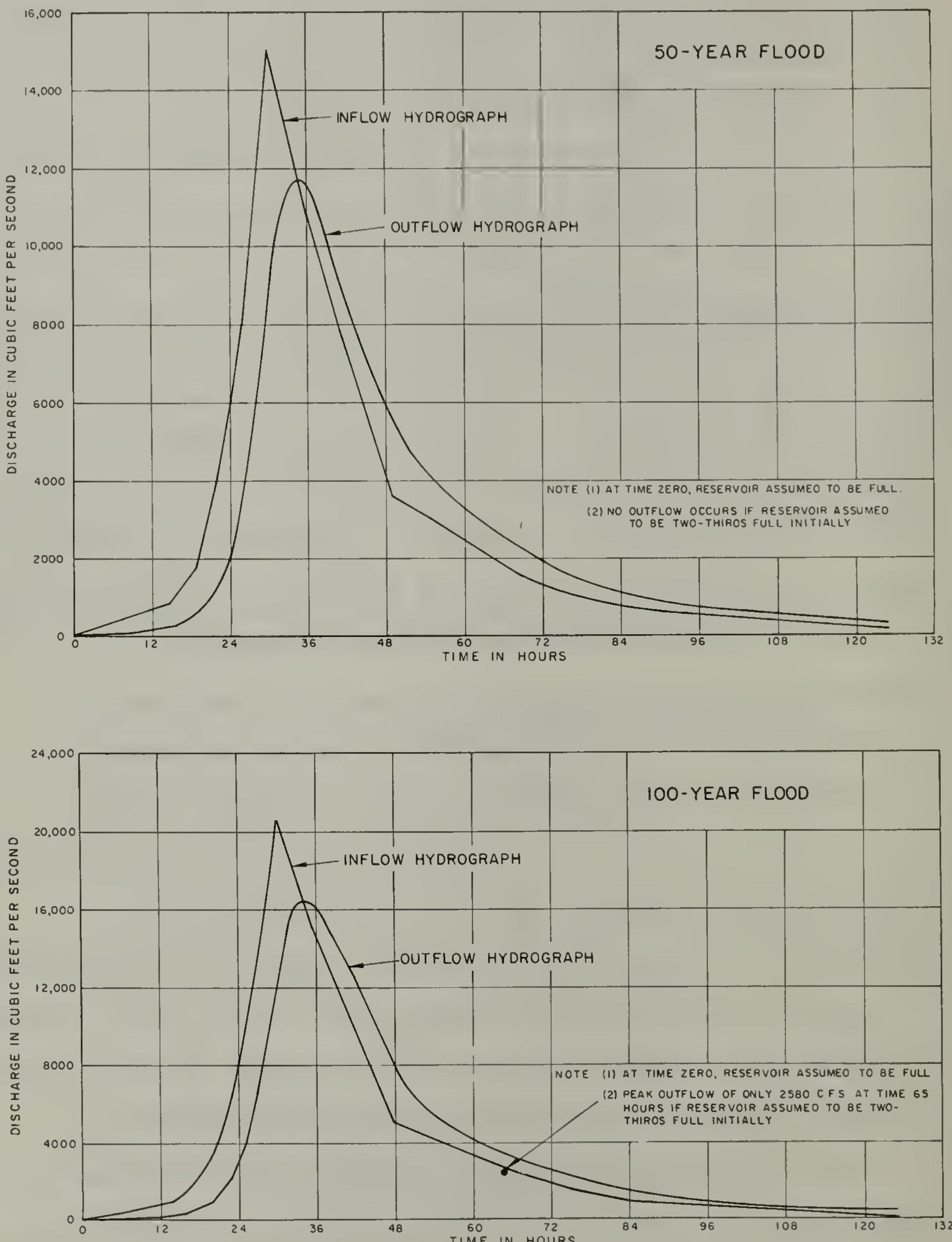
FIGURE C-4



INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT SAN VICENTE RESERVOIR

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

flood with the reservoir initially full, the inflow and outflow peaks were 15,000 and 11,700 cubic feet per second, respectively, with five hours lag in peaks.

For the condition of reservoir two-thirds full initially, the outflow peak discharge for a 100-year flood was only 2,580 cubic feet per second. There was no reservoir spill for a 50-year flood with the reservoir two-thirds full initially.

Stream Flood Routing

By utilization of the method described in Appendix B, the outflows from El Capitan and San Vicente Reservoirs resulting from the 100-year flood, with reservoirs initially full, were routed individually to Mission Gorge. In each case the stream reach from the dam to Mission Gorge was divided into three approximately equal segments and an outflow hydrograph was developed at the end of each of the subdivided reaches, the final one being at Mission Gorge.

The travel time, T, for each reach was determined by estimating the velocity of the flood wave from the data published in U. S. Geological Survey Water Supply Paper 426 for the flood of January 27, 1916. From the published peaking times for the flood at points 8.5 miles upstream from Old Mission Dam in Mission Gorge and 12.5 miles downstream from Old Mission Dam, the velocity of the flood wave was determined to be about 7.6 feet per second, which was slightly higher than the average velocities calculated for various peak discharges ranging from 50,000 to 20,000 cubic feet per second.

By utilizing the computed value of 7.6 feet per second for each of the subdivided reaches to determine the value of T, the outflow hydrographs were generated at the end of each subreach by use of Equation 7 in Appendix B. An increment of one hour was used for the routing period, T.

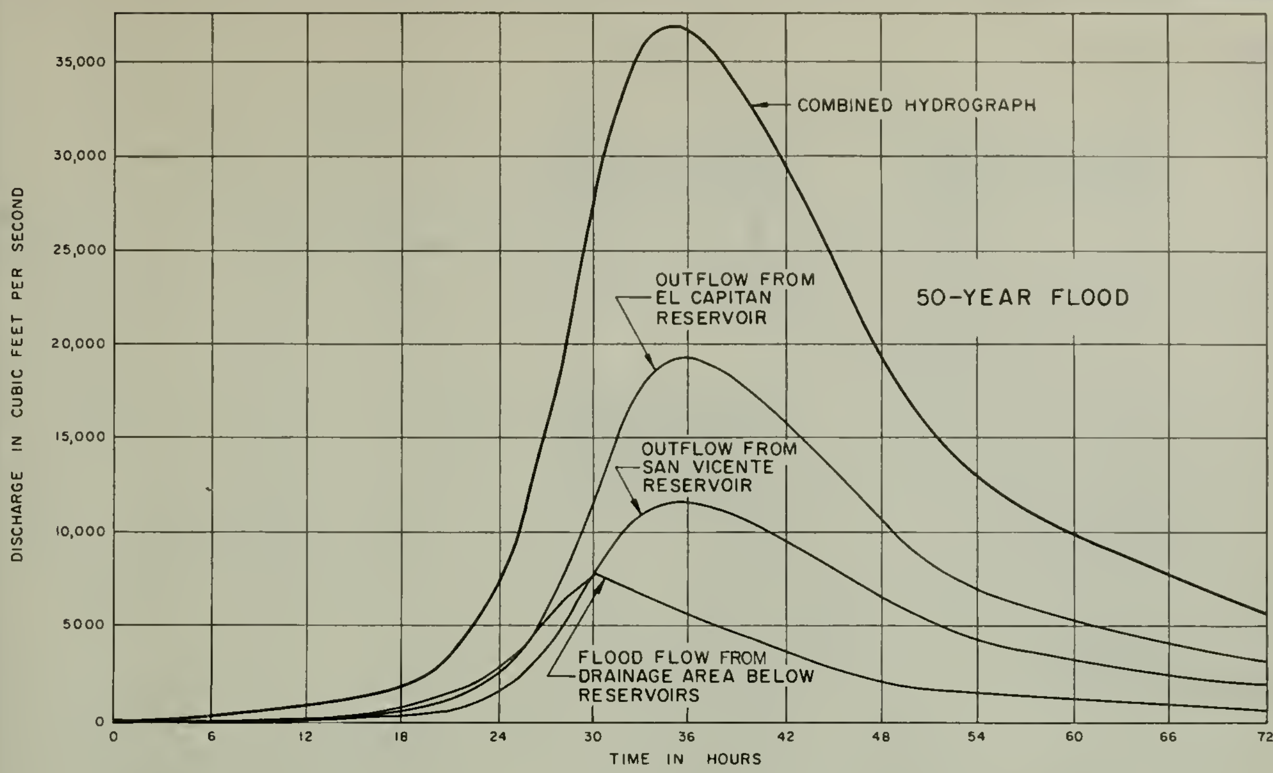
Determination of Total Peak Flood Flows

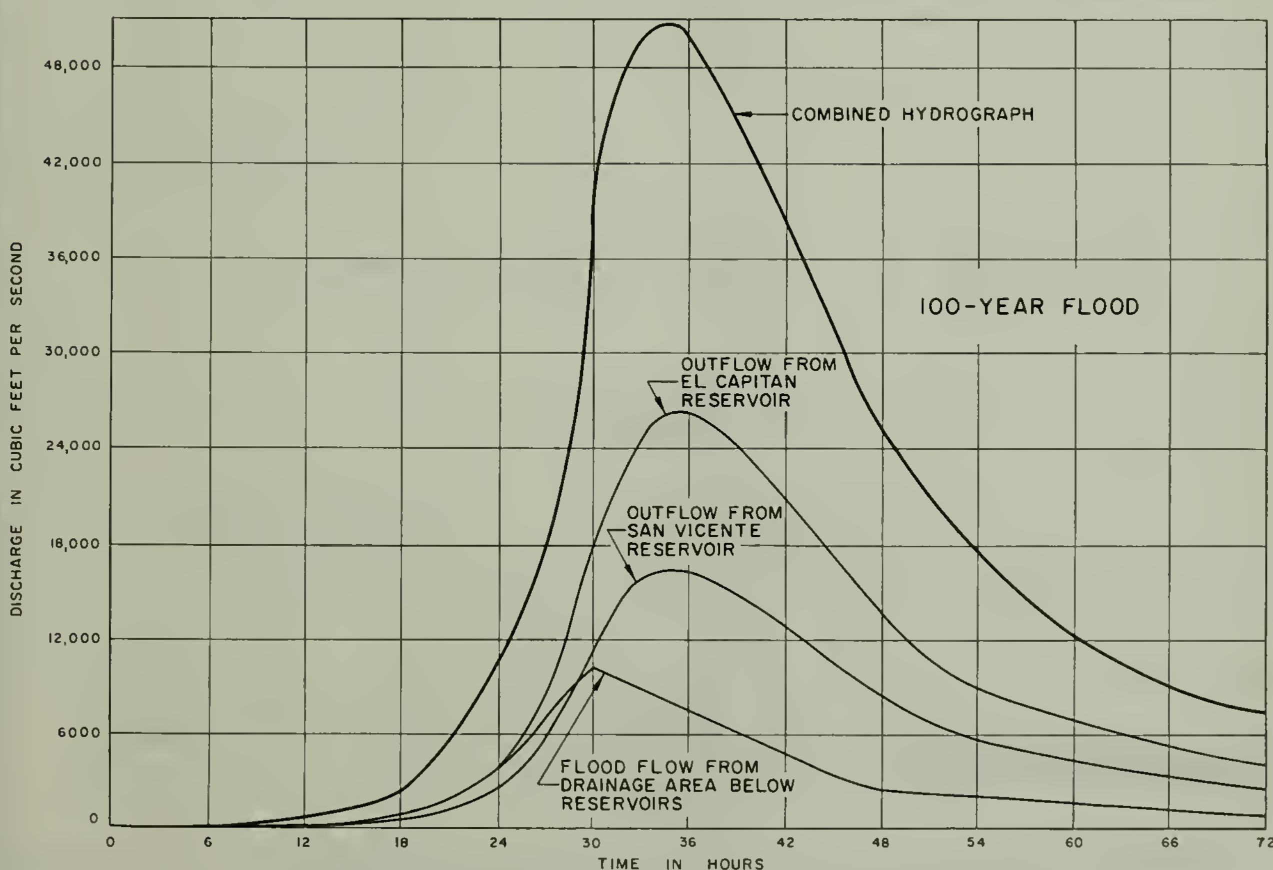
The peak flood flows at each selected point along the reach of the San Diego River under study were determined by combining flood hydrographs of the routed overflows from the dam spillways with the hydrographs of the contributing areas below the reservoirs.

The combined hydrographs for 50- and 100-year floods, with reservoirs initially full, at the confluence of San Diego River and San Vicente Creek are shown on Figure C-5, and the hydrographs at Mission Gorge are presented on Figure C-6.

For the initial condition of reservoirs partially full, the spill from the reservoirs did not add to the peak because of the considerable time lapse between the earlier peak flow from the tributary areas below the dams and the subsequent peak reservoir spill. The total peak discharge, therefore, was the discharge determined for the tributary area below the reservoirs, as shown on Figures C-7 and C-8. These peaks correspond to the values shown in Table 2.

Magnitudes of peak discharges for the 50- and 100-year floods at selected points along the San Diego River for the assumed condition of reservoirs full initially are set forth in Table 3. It will be noted that the partial discharges tabulated for each area contributing to the peak discharge are the discharges taken from the individual hydrographs directly below the maximum discharge on the combined hydrograph, and that this value may not be the maximum discharge for the smaller hydrographs due to the influence of lag time.





FLOOD HYDROGRAPHS AT CONFLUENCE OF SAN DIEGO RIVER AND SAN VICENTE CREEK FOR 50-YEAR AND 100-YEAR FLOODS

ASSUMING FULL RESERVOIR CONDITIONS

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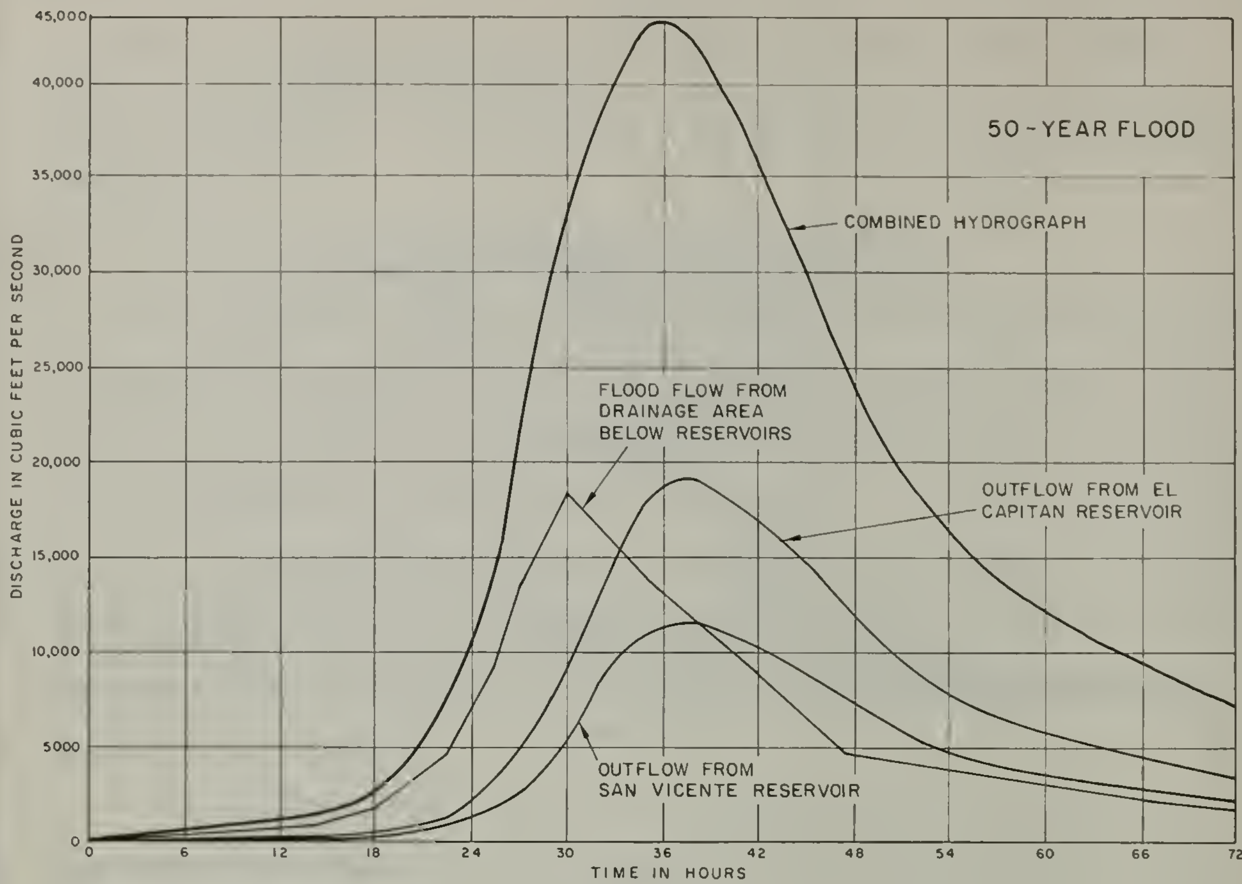
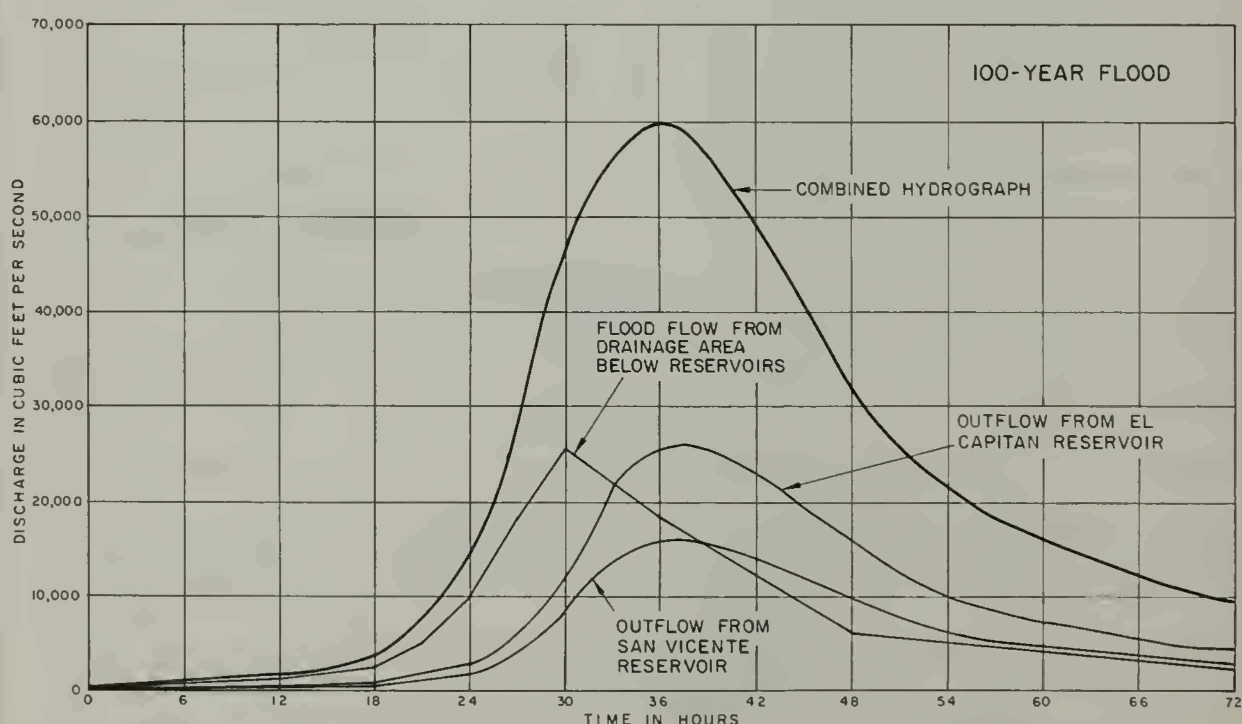
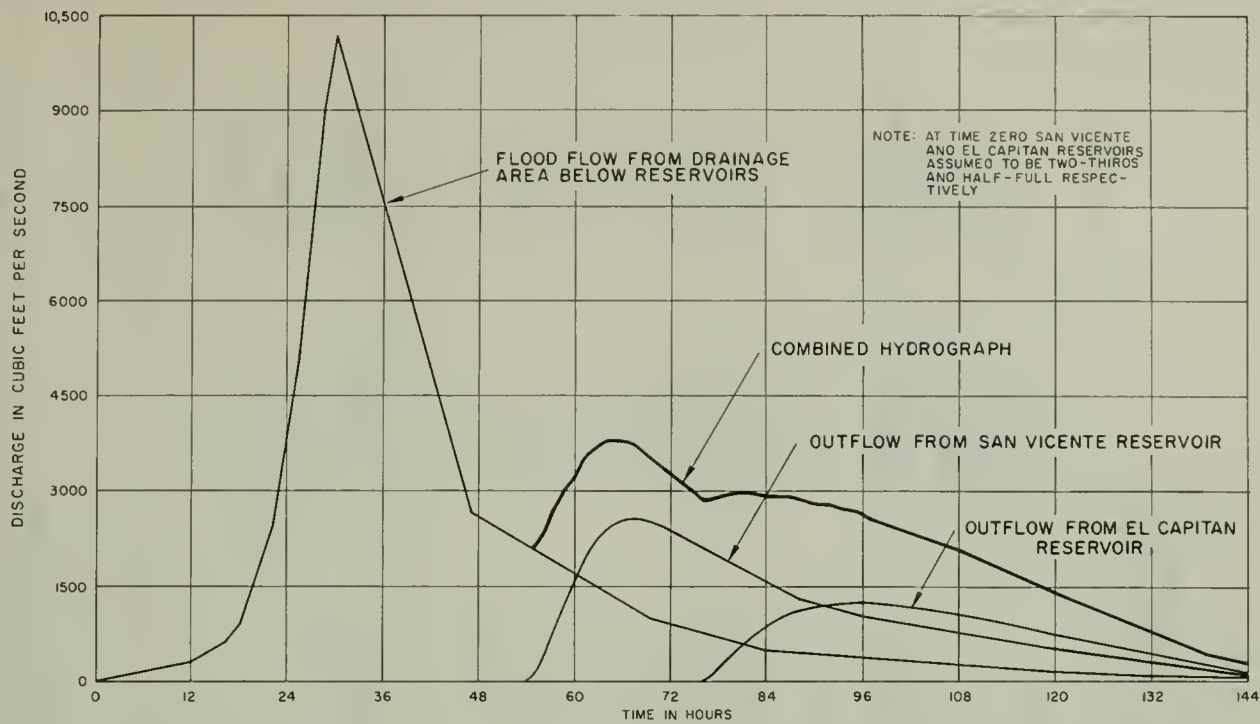
FIGURE C-6





FLOOD HYDROGRAPHS AT MISSION GORGE FOR
50-YEAR AND 100-YEAR FLOODS
ASSUMING FULL RESERVOIR CONDITIONS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964



FLOOD HYDROGRAPH AT CONFLUENCE OF SAN DIEGO RIVER AND SAN VICENTE CREEK FOR 100-YEAR FLOOD

ASSUMING PARTLY FULL RESERVOIR CONDITIONS

FIGURE C-8

FLOOD HYDROGRAPH AT MISSION GORGE FOR 100-YEAR FLOOD

ASSUMING PARTLY FULL RESERVOIR CONDITIONS

TABLE 3

ESTIMATED TOTAL PEAK FLOOD DISCHARGES FOR SELECTED LOCATIONS ON THE SAN DIEGO RIVER, ASSUMING FULL RESERVOIR CONDITIONS

In cubic feet per second

Location	Routed reservoir discharge		Flood discharges from area below reservoirs	Total peak discharge
	El Capitan Reservoir	San Vicente Reservoir		
	50-Year Flood			
Old Mission Dam	18,500	11,500	13,000	43,000
Approx. 0.7 mile downstream from Sycamore Canyon	19,000	11,500	11,500	42,000
Confluence of Forester Creek and San Diego River	19,000	11,500	10,500	41,000
Approx. 0.5 mile downstream from Santee	19,000	11,500	9,000	39,500
Cottonwood Road	19,000	11,500	8,000	38,500
Approx. 0.8 mile downstream from Lakeside	19,000	11,500	7,500	38,000
Confluence of San Vicente Creek and San Diego River	19,000	11,500	6,000	36,500
Confluence of Wildcat Canyon and San Diego River	19,000	--	5,000	24,000
Approx. 2 miles downstream from El Monte Park	19,500	--	3,000	22,500

ESTIMATED TOTAL PEAK FLOOD DISCHARGES FOR SELECTED LOCATIONS ON THE SAN DIEGO RIVER, ASSUMING FULL RESERVOIR CONDITIONS
(continued)

In cubic feet per second

Location	Routed reservoir discharge: El Capitan Reservoir	Routed reservoir discharge: San Vicente Reservoir	Flood discharge from area below reservoirs	Total peak discharge
	100-Year Flood			
Old Mission Dam	25,500	16,000	18,500	60,000
Approx. 0.7 mile downstream from Sycamore Canyon	26,000	16,000	15,500	57,500
Confluence of Forester Creek and San Diego River	26,000	16,000	14,000	56,000
Approx. 0.5 mile downstream from Santee	26,000	16,000	12,500	54,500
Cottonwood Road	26,000	16,000	11,000	53,000
Approx. 0.8 mile downstream from Lakeside	26,000	16,000	9,500	51,500
Confluence of San Vicente Creek and San Diego River	26,500	16,500	8,000	51,000
Confluence of Wildcat Canyon and San Diego River	26,500	--	7,000	33,500
Approx. 2 miles downstream from El Monte Park	26,500	--	4,000	30,500

CHAPTER III. AREAS OF POTENTIAL INUNDATION

This chapter describes the final step in the study--determination of the areas of potential inundation along the San Diego River and San Vicente Creek from Mission Gorge to El Capitan and San Vicente Reservoirs for 50- and 100-year floods. The study was conducted for two different assumed reservoir conditions: (1) both El Capitan and San Vicente Reservoirs initially full, and (2) El Capitan Reservoir one-half full and San Vicente Reservoir two-thirds full initially.

Backwater Curve Computations

By use of Equation (9) in Appendix B, backwater curves were computed for discharges ranging from 60,000 to 20,000 cubic feet per second for the lower reaches and 37,000 to 5,000 cubic feet per second for the upper reaches of the San Diego River under investigation. A total of 89 cross sections were selected on the 19-mile-long reaches of the San Diego River and San Vicente Creek. The distance between cross sections varied from about 100 feet to about 4,100 feet, with the average distance being about 1,050 feet. The roughness coefficient, n, in the Manning formula varied from .028 to .070. The energy coefficient, α, varied from 1.00 to 1.40, with the average being about 1.10.

The use of the standard step method of backwater computations requires the establishment of an initial water-surface elevation at the beginning of calculations. The initial water-surface elevation in the vicinity of the Old Mission Dam in Mission Gorge, the most downstream point of the investigational area, was established by a relationship derived from data published in U. S. Geological Survey Water Supply

Paper 426. These data for floods of February 11, 1915, and January 27, 1916, are shown in columns (1) through (5) of Table 4.

TABLE 4

STAGE-DISCHARGE RELATIONSHIP FOR SAN DIEGO RIVER FOR FLOODS OF 1915 AND 1916 AT MISSION GORGE JUST ABOVE OLD MISSION DAM

Date	Discharge, in cubic feet per second (1)	Roughness* coefficient "n" (2)	Gage height, in feet (3)	Water-surface elevation, in feet (4)	Streambed elevation, in feet (5)	Depth of flow, in feet (6)	Normal depth, in feet (7)	Amount of backwater, in feet (8)
Feb. 11, 1915	3,960	0.03	13.6	280.0	275	5	4.8	0.2
Jan. 27, 1916	70,200	0.03	25.1	291.5	275	16.5	14.8	1.7

*Manning's formula

The normal depth, column (7), was calculated by using a roughness coefficient, n, of 0.030 in the Manning formula and the slope of the stream channel as determined from topographic maps. The amount of backwater, column (8), was calculated as the difference between the gaged depth of flow and normal depth. From the known discharges and the calculated amount of backwater, the following approximate relationship was developed for Mission Gorge:

$$\frac{WS_1 - d_1}{WS_2 - d_2} = \frac{h_1}{h_2} = \left(\frac{Q_1}{Q_2}\right)^{2/3} \qquad (1)$$

where:

WS_1 and WS_2 = water-surface elevation for conditions (1) and (2), in feet

d_1 and d_2 = elevation of the water surface for normal depth for conditions (1) and (2), in feet

h_1 and h_2 = amount of backwater for conditions (1) and (2), in feet

Q_1 and Q_2 = discharge for conditions (1) and (2), in cubic feet per second

By assuming the amount of backwater and the discharge for the flood of January 27, 1916, as condition (1) and substituting, equation (1) becomes:

$$\frac{1.7}{h_2} = \left(\frac{70,200}{Q_2}\right)^{2/3} \tag{2}$$

As flow at this point on the San Diego River is subcritical, the initial water-surface elevation in all cases was found by calculating h_2 for a given discharge Q_2 and adding this amount of backwater to the normal water-surface elevation for the given discharge. The normal water-surface elevation was found by trial and error solution of the Manning formula with the slope of the hydraulic grade line equal to the slope of the streambed.

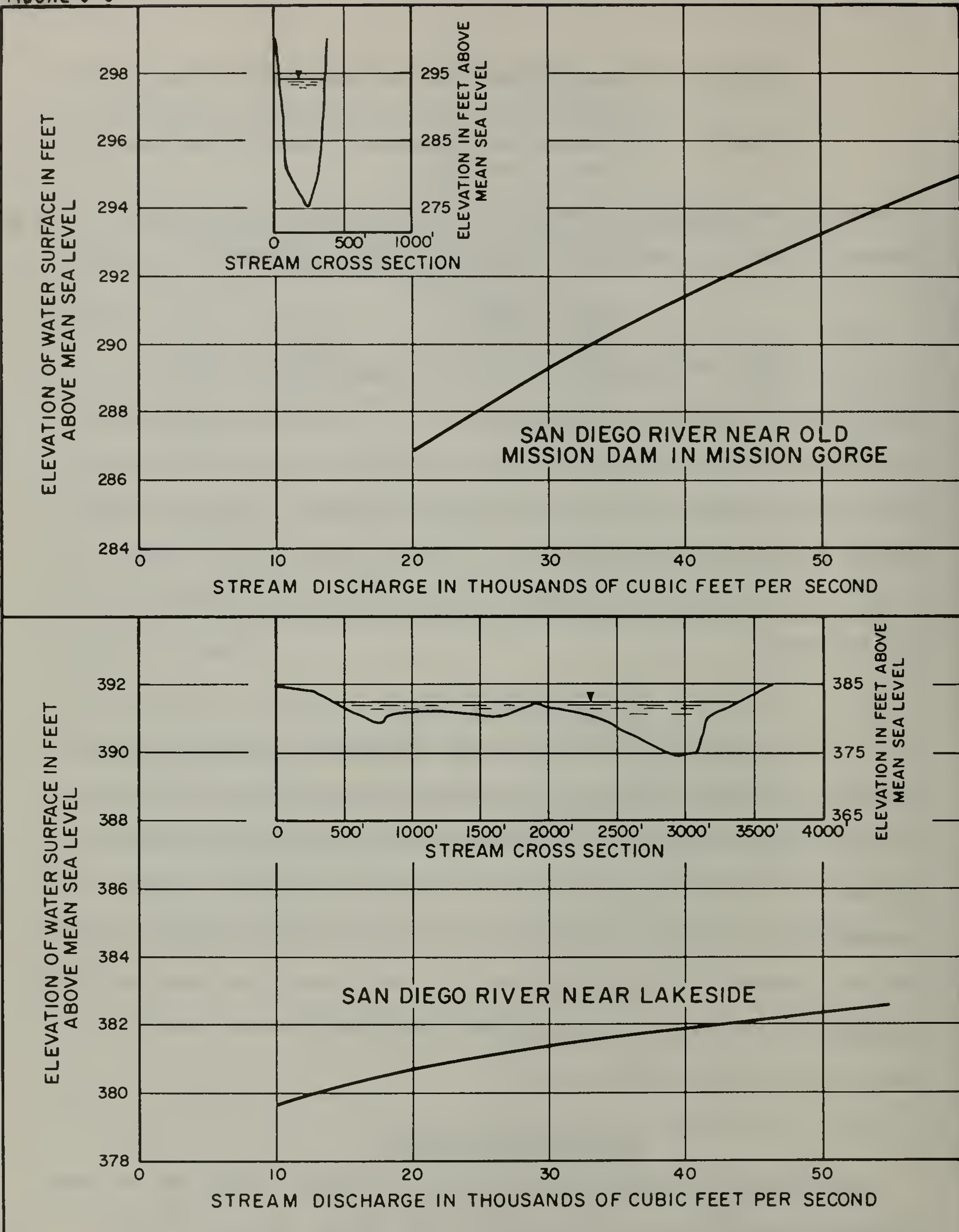
Stage-Discharge Curves

As stated, backwater curves were computed for various discharges spanning the range of flood peaks presented in Tables 2 and 3. From the results of these backwater curve computations, state-discharge curves were plotted at selected points along the San Diego River. Typical stage-discharge curves for San Diego River near Old Mission Dam in Mission Gorge and near Lakeside are shown on Figure C-9. These curves were then used to determine the stage at selected locations for the computed peak discharges presented in Tables 2 and 3.

Water-Surface Profiles

From the peak discharges presented in Tables 2 and 3 and the stage-discharge curves for particular points on the stream, the water-surface

FIGURE C-9



TYPICAL STREAM CROSS SECTIONS AND STAGE DISCHARGE CURVES

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

elevations were determined and the water-surface profile drawn. A straight line variation in the water-surface profile was assumed between any two successive sections where the stage-discharge relationship was derived. A total of 79 points for the San Diego River and 10 points for San Vicente Creek were utilized in determining the water-surface profile.

Areas of Potential Inundation

From the water-surface profiles, the elevations of the flood-waters at any point along the river could be ascertained. Areas which would be subject to inundation were then delineated upon topographic maps at a scale of 1 inch equals 200 feet. For purposes of presentation in this report, the areas of potential inundation were delineated on plates at a scale of 1 inch equals 2,000 feet.

Condition of Reservoirs Partially Full Initially

Plates C-2A, C-2B, and C-2C show the areas of potential inundation for floods of 50- and 100-year recurrence intervals assuming El Capitan Reservoir is one-half full and San Vicente Reservoir is two-thirds full, initially. There is only a small difference in the areas inundated by the 50- and 100-year flood; therefore, the lines delineating the areas closely parallel each other. The difference in water-surface elevation for the 50- and 100-year floods was less than one foot for almost the entire reach of channel under the assumed conditions.

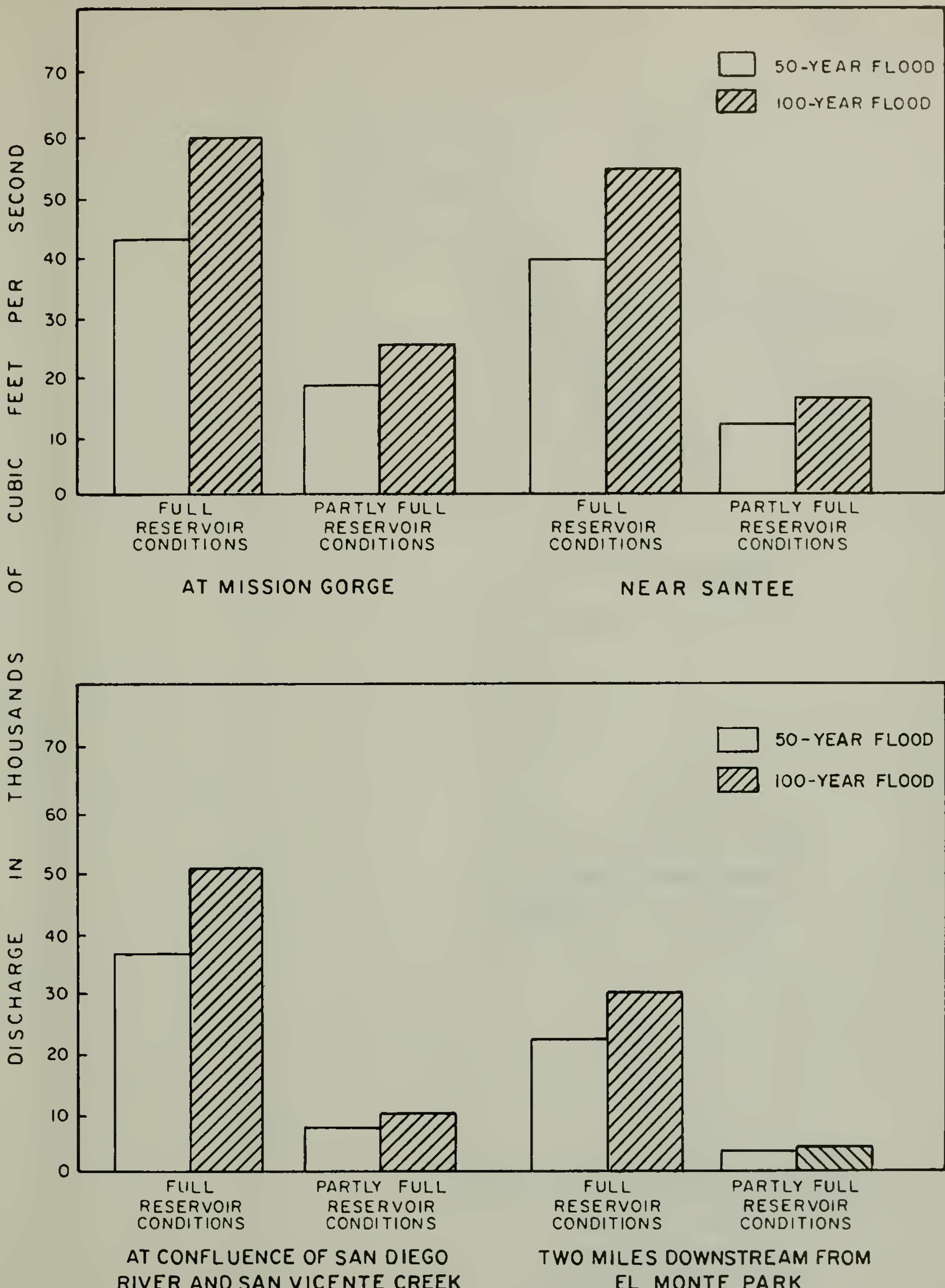
Condition of Reservoirs Full Initially

Plates C-3A, C-3B, and C-3C show the areas of potential inundation for 50- and 100-year floods, assuming that El Capitan and San Vicente

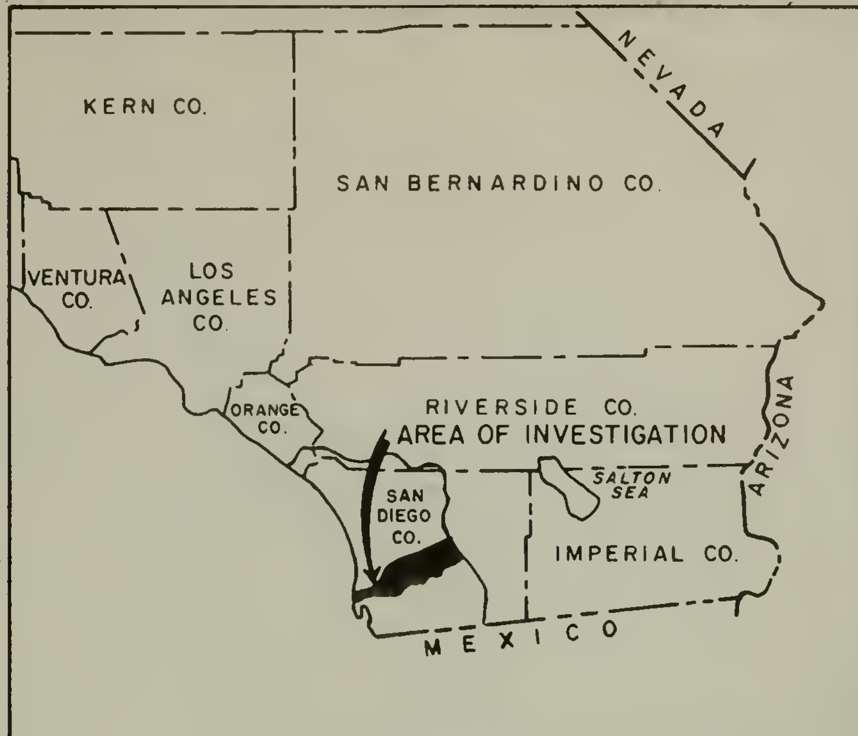
Reservoirs are full initially. The difference in areas inundated is more pronounced with the reservoirs initially full. The attenuating effect of the full reservoirs is less significant. Therefore, the areas inundated by the 100-year floods are considerably larger than the areas inundated by the 50-year floods. The difference in water-surface elevations for the 50- and 100-year floods varied from about 3.2 feet near Old Mission Dam in Mission Gorge to about 0.6 foot near Lakeside.

Summary of Peak Flood Discharges

A summary of the peak flood discharges for the 50- and 100-year floods at selected locations along the San Diego River for the assumed conditions at reservoirs full initially, and reservoirs partly full initially, is shown in Figure C-10.



SUMMARY OF PEAK FLOOD DISCHARGES AT SELECTED LOCATIONS ON THE SAN DIEGO RIVER



LOCATION MAP

LEGEND

RIVER BASIN DRAINAGE BOUNDARY

SUBAREA DRAINAGE BOUNDARY

AREA INVESTIGATED FOR POSSIBLE INUNDATION

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

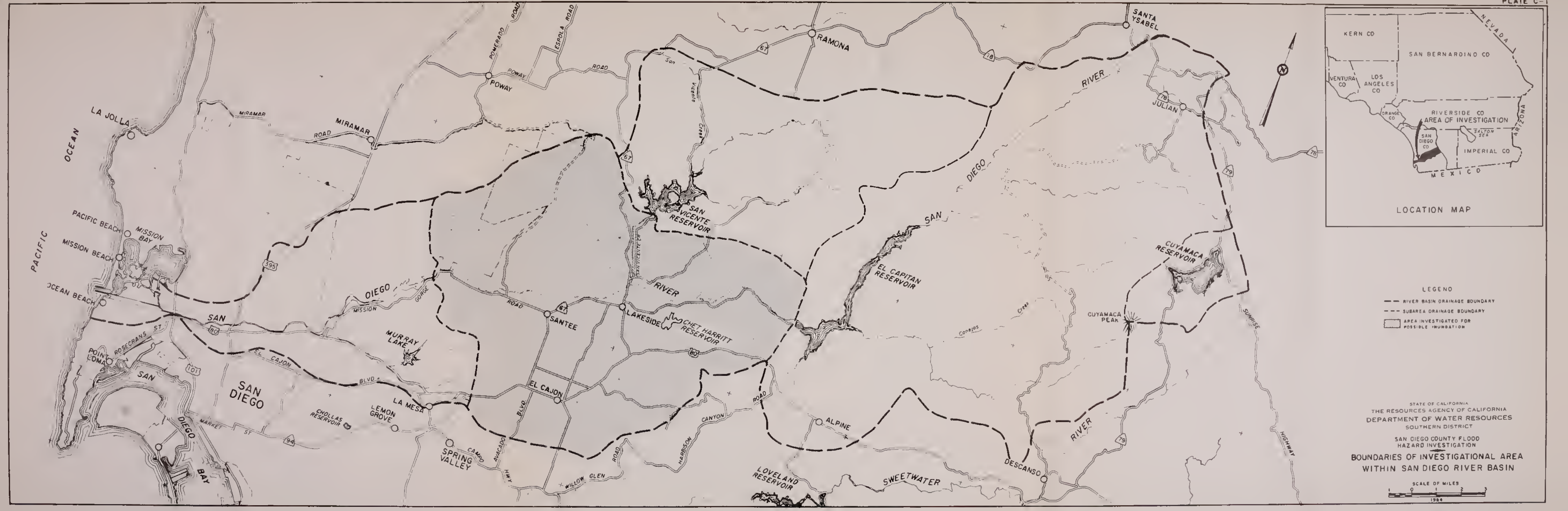
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

BOUNDARIES OF INVESTIGATIONAL AREA WITHIN SAN DIEGO RIVER BASIN

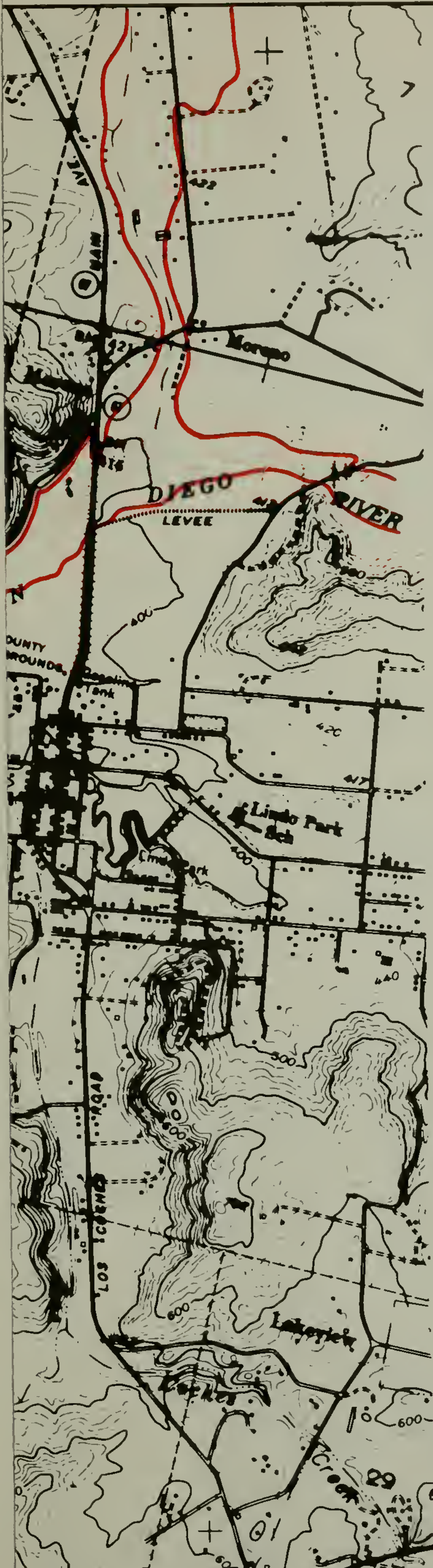
SCALE OF MILES

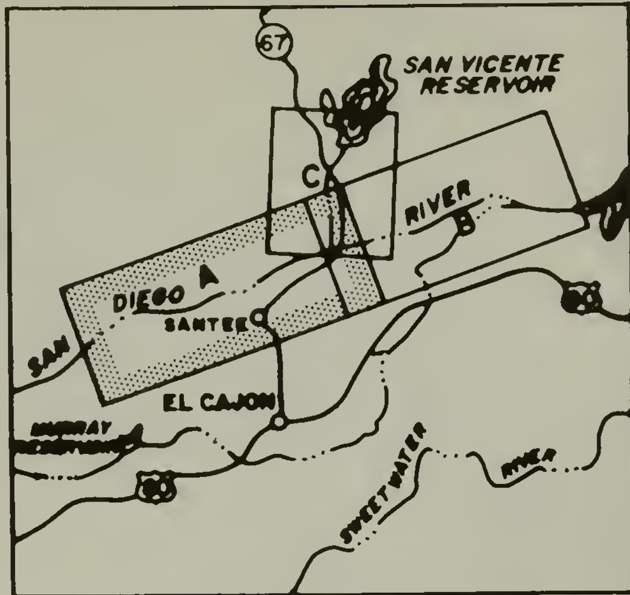
1 0 1 2 3

1964



PACIFIC
OCEAN
LA JOLLA
PACIFIC BEACH
MISSION BAY
MISSION BEACH
OCEAN BEACH
POINT LOMA
SAN DIEGO
SAN DIEGO BAY
MIRAMAR
MIRAMAR ROAD
POWAY
POWAY ROAD
POMERADO ROAD
ESPOLA ROAD
RAMONA
SANTA YSABEL
JULIAN
SAN VICENTE RESERVOIR
San Vicente Creek
SAN DIEGO RIVER
MISSION GORGE
SANTEE
LAKESIDE
CHET HARRITT RESERVOIR
MURRAY LAKE
EL CAJON
EL CAJON BLVD
LA MESA
LEMON GROVE
CHOLLAS RESERVOIR
SPRING VALLEY
ROSECRANS ST
MARKET ST
EL CAPITAN RESERVOIR
Conejos Creek
CUYAMACA RESERVOIR
CUYAMACA PEAK
ALPINE
DESCANSO
HARBISON CANYON ROAD
WILLOW GLEN ROAD
LOVELAND RESERVOIR
SWEETWATER
SUNRISE HIGHWAY
LOCATION MAP
KERN CO
SAN BERNARDINO CO
NEVADA
VENTURA CO
LOS ANGELES CO
ORANGE CO
RIVERSIDE CO
AREA OF INVESTIGATION
SAN DIEGO CO
SALTON SEA
IMPERIAL CO
ARIZONA
MEXICO
LEGEND
RIVER BASIN DRAINAGE BOUNDARY
SUBAREA DRAINAGE BOUNDARY
AREA INVESTIGATED FOR POSSIBLE INUNDATION
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD
HAZARD INVESTIGATION
BOUNDARIES OF INVESTIGATIONAL AREA
WITHIN SAN DIEGO RIVER BASIN
SCALE OF MILES
1964





KEY MAP

LEGEND

INUNDATED AREA FOR 50 AND 100 YEAR FLOODS

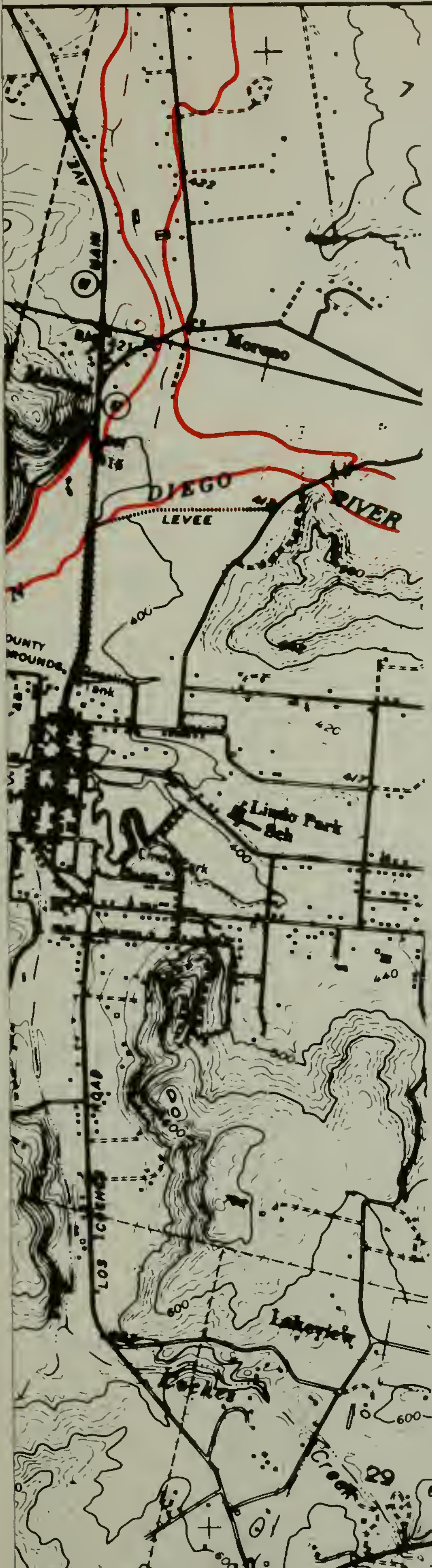
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

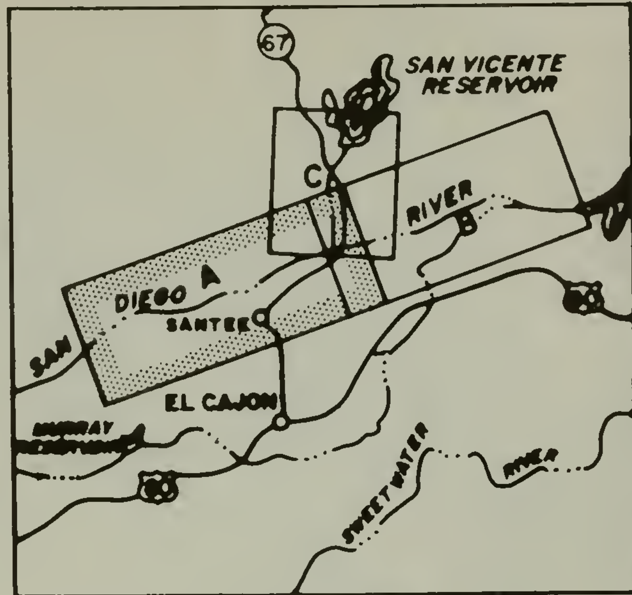
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN DIEGO RIVER– AREAS OF POTENTIAL INUNDATION WHEN RESERVOIRS PARTIALLY FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000

1964





KEY MAP

LEGEND

INUNDATED AREA FOR 50 AND 100 YEAR FLOODS

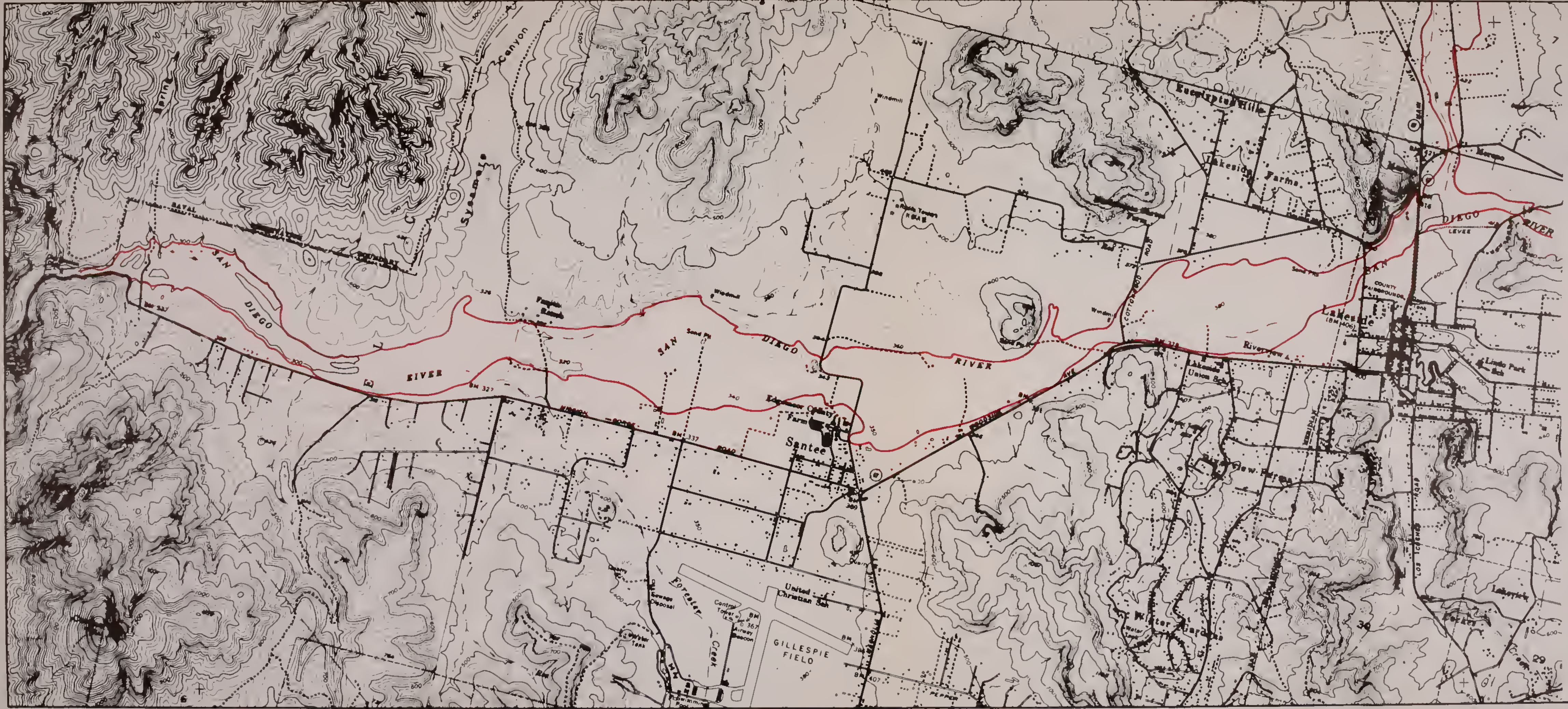
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

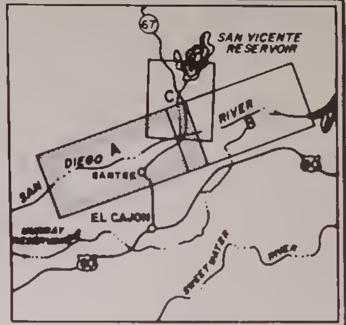
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN DIEGO RIVER–
AREAS OF POTENTIAL INUNDATION WHEN RESERVOIRS PARTIALLY FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000

1964





KEY MAP

LEGEND

INUNDATED AREA FOR 50 AND 100 YEAR FLOODS

STATE OF CALIFORNIA
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DEPARTMENT OF WATER RESOURCES
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SAN DIEGO RIVER–
AREAS OF POTENTIAL INUNDATION WHEN RESERVOIRS PARTIALLY FULL INITIALLY

SCALE OF FEET
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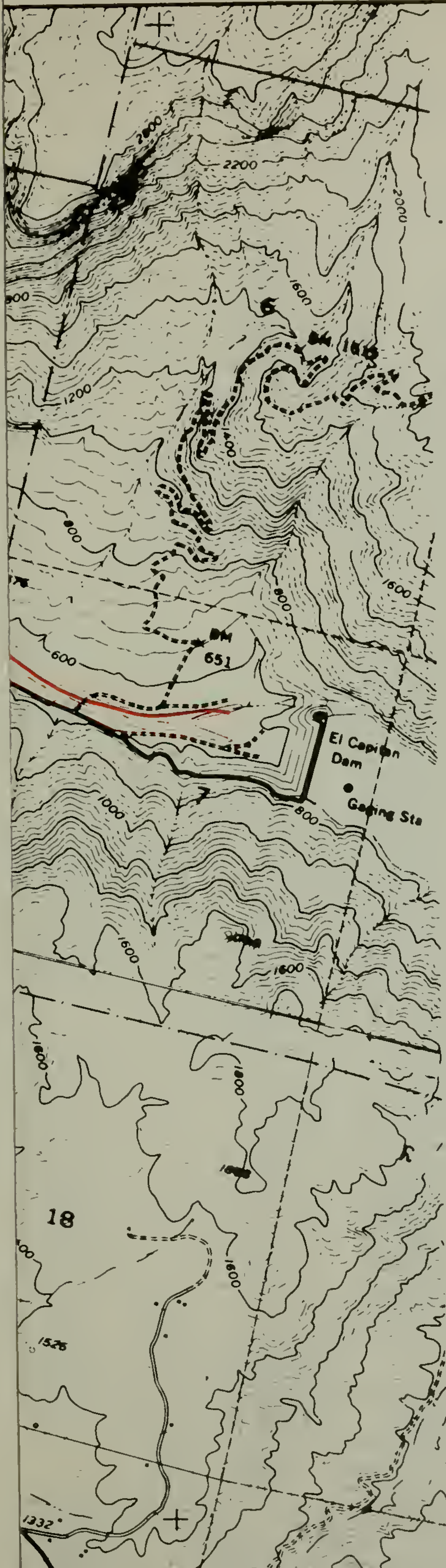

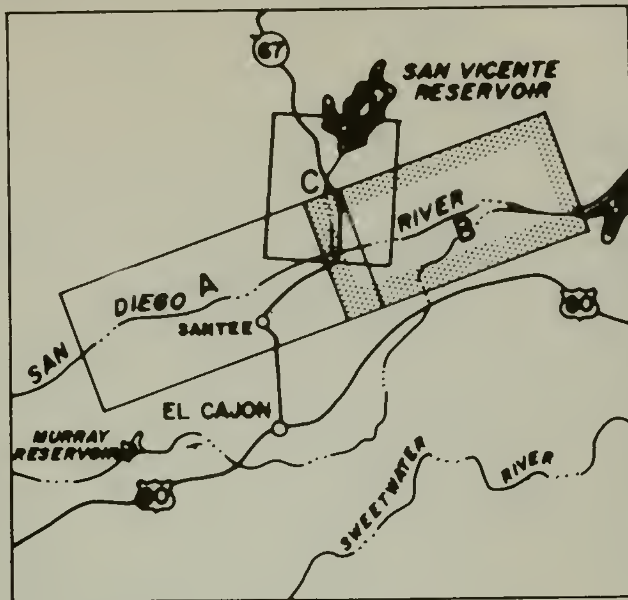

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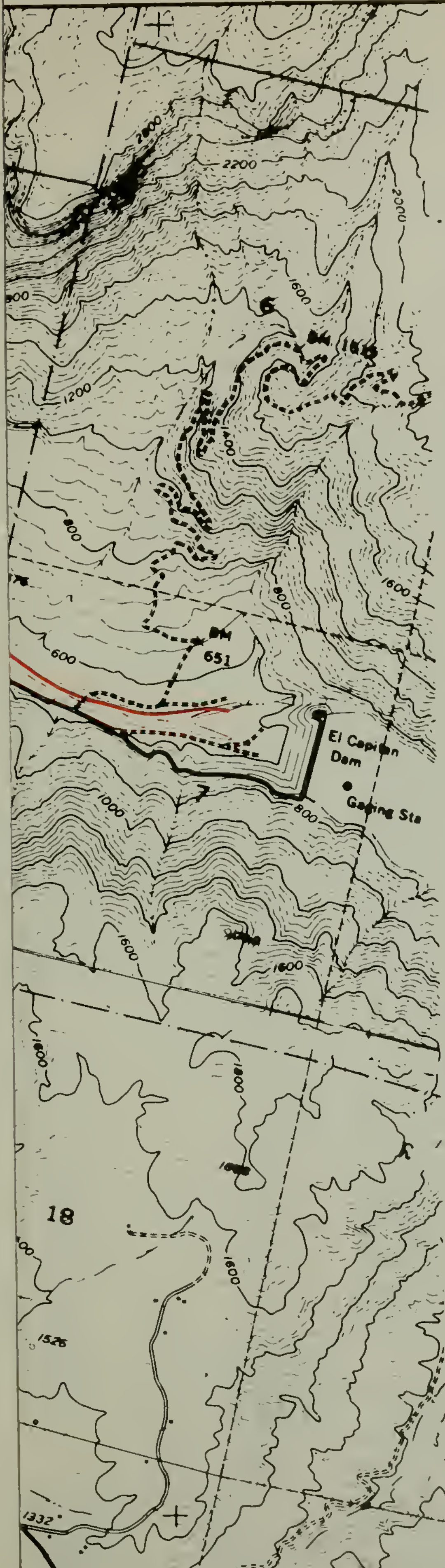

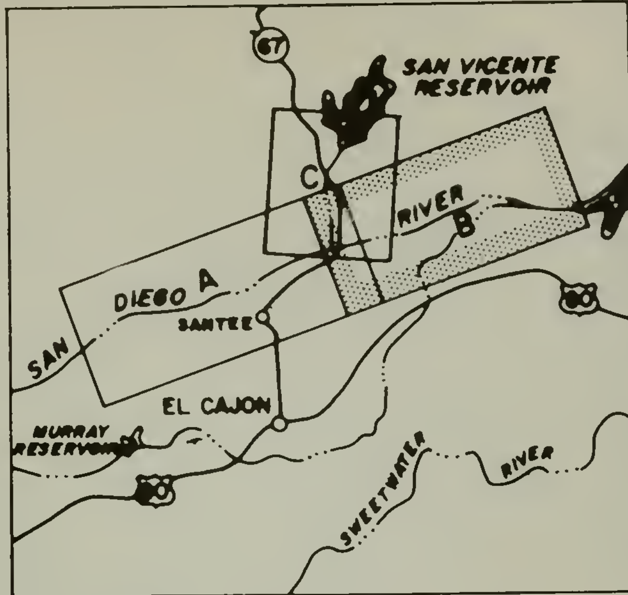

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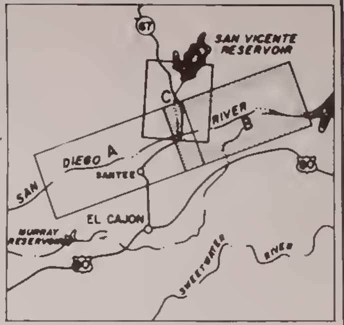

KEY MAP

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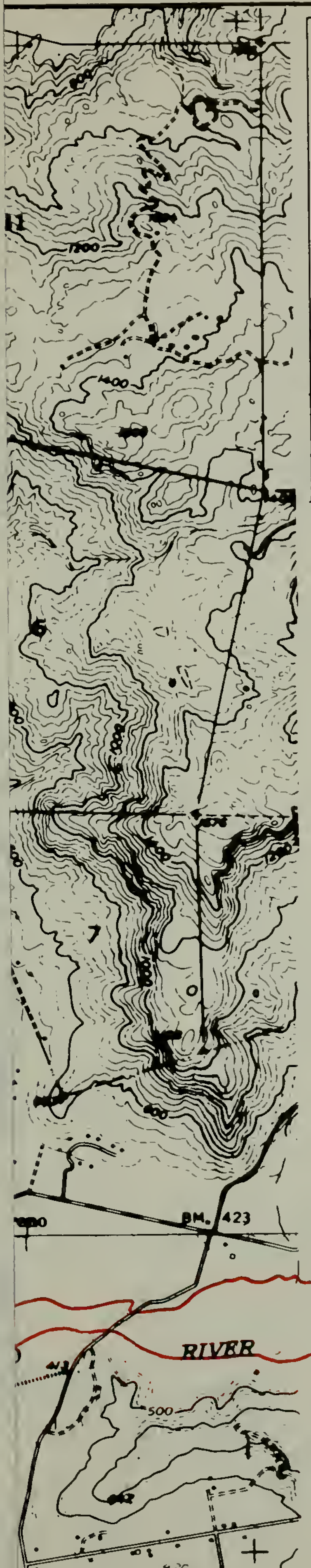

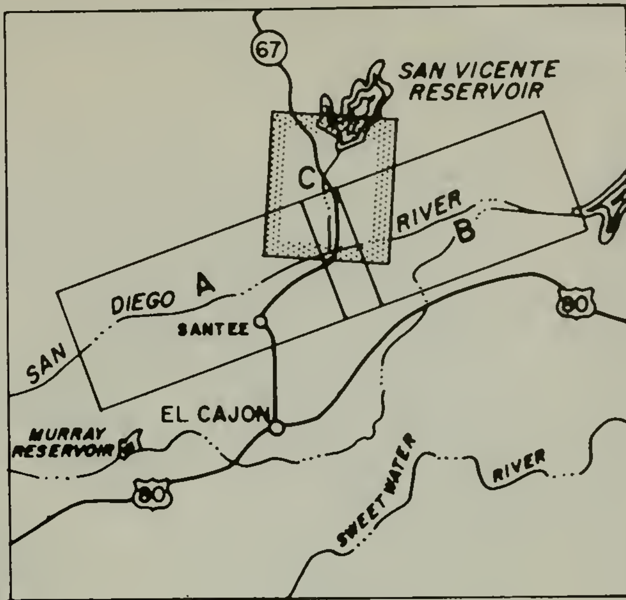

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INUNDATED AREA FOR 50 AND 100 YEAR FLOODS

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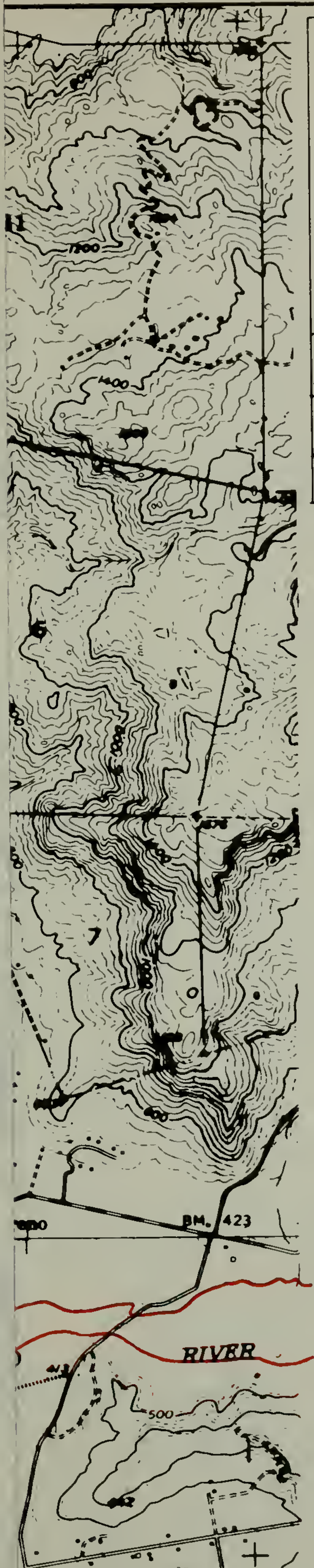

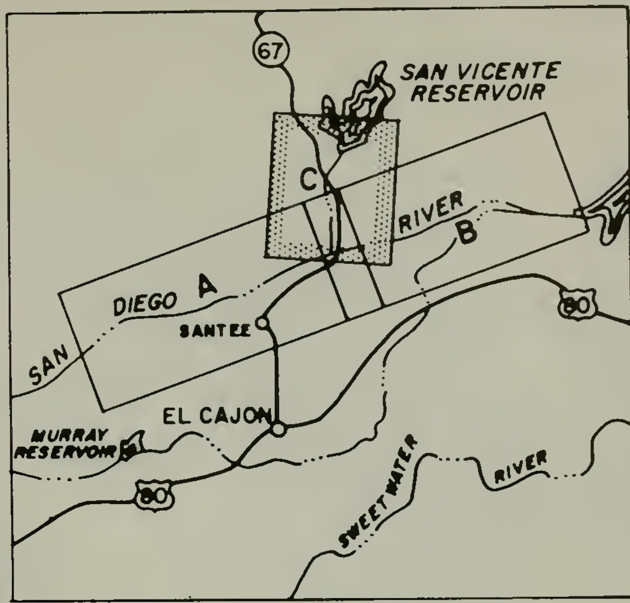

KEY MAP

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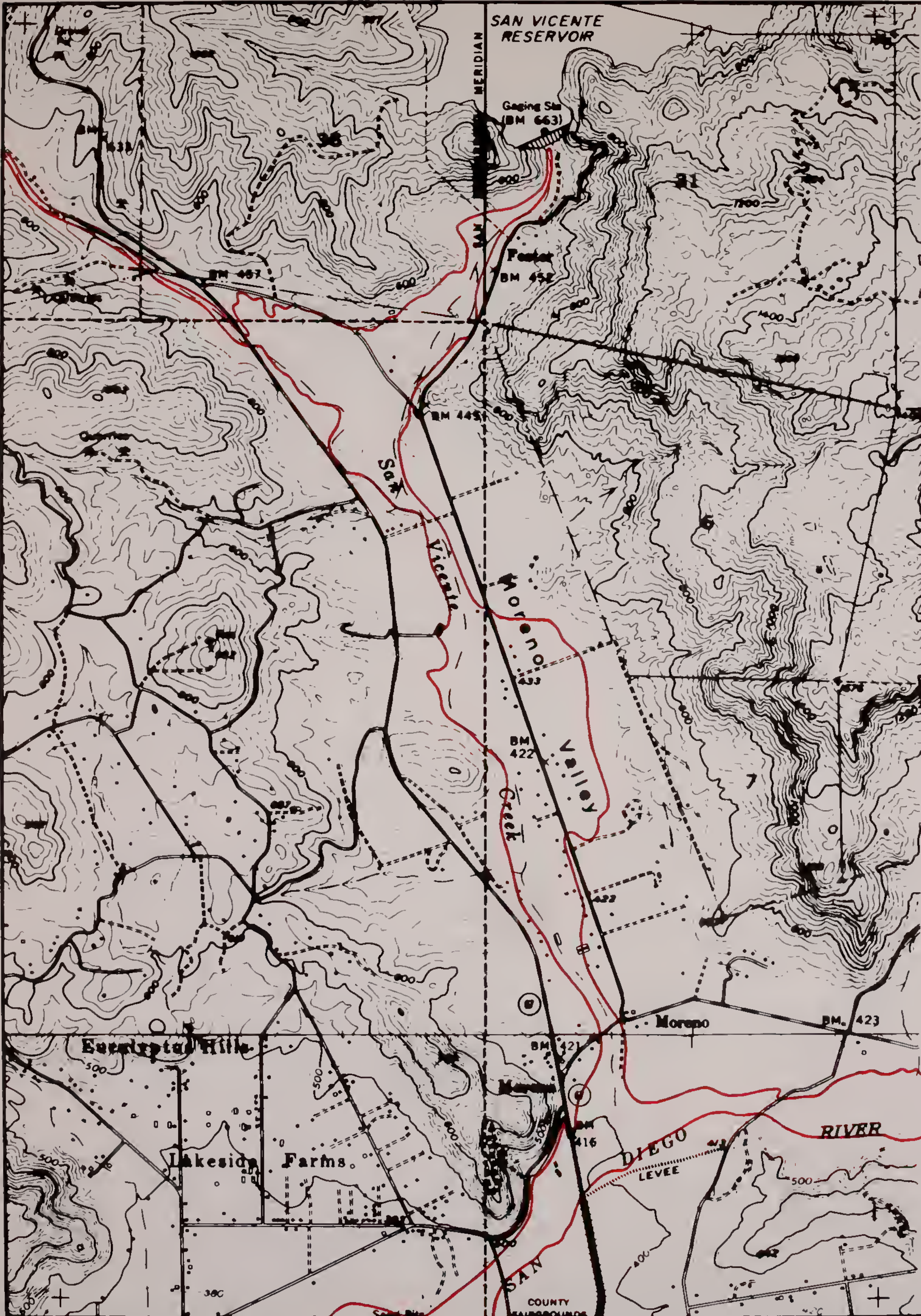

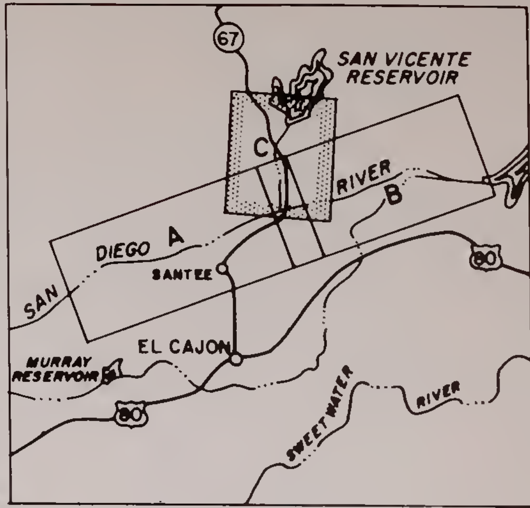

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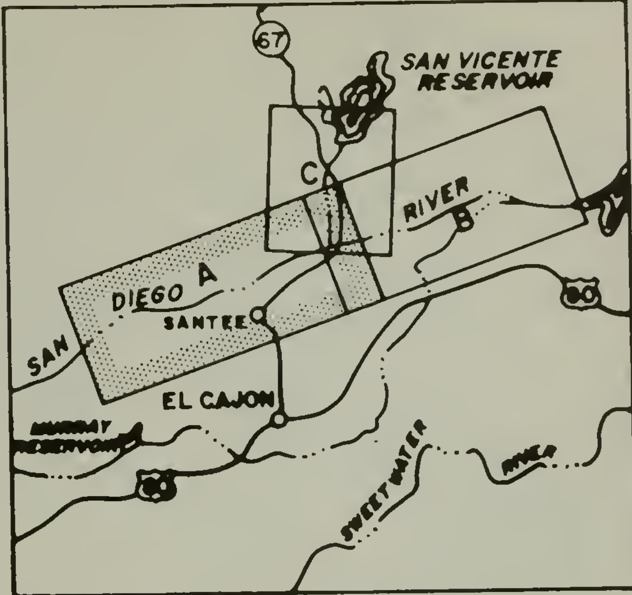

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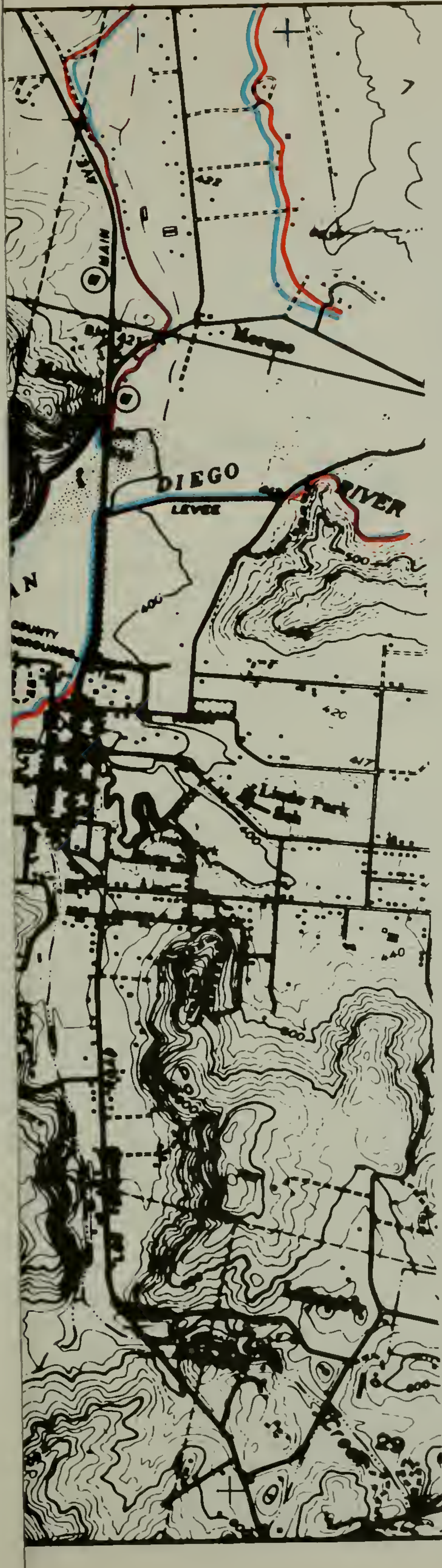

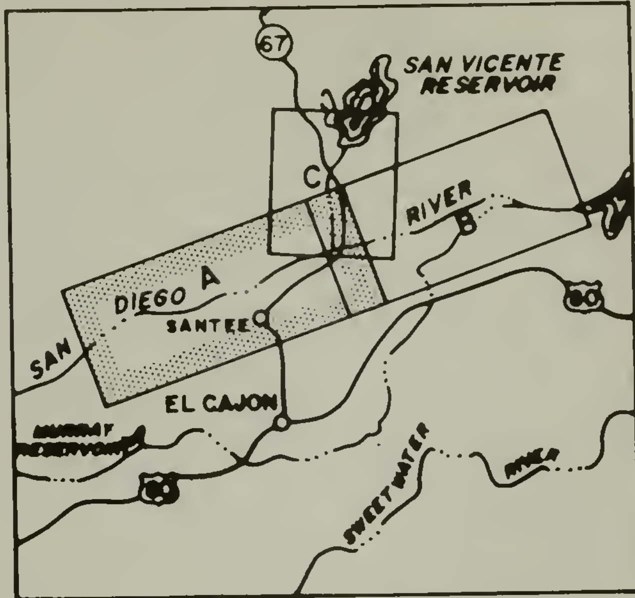

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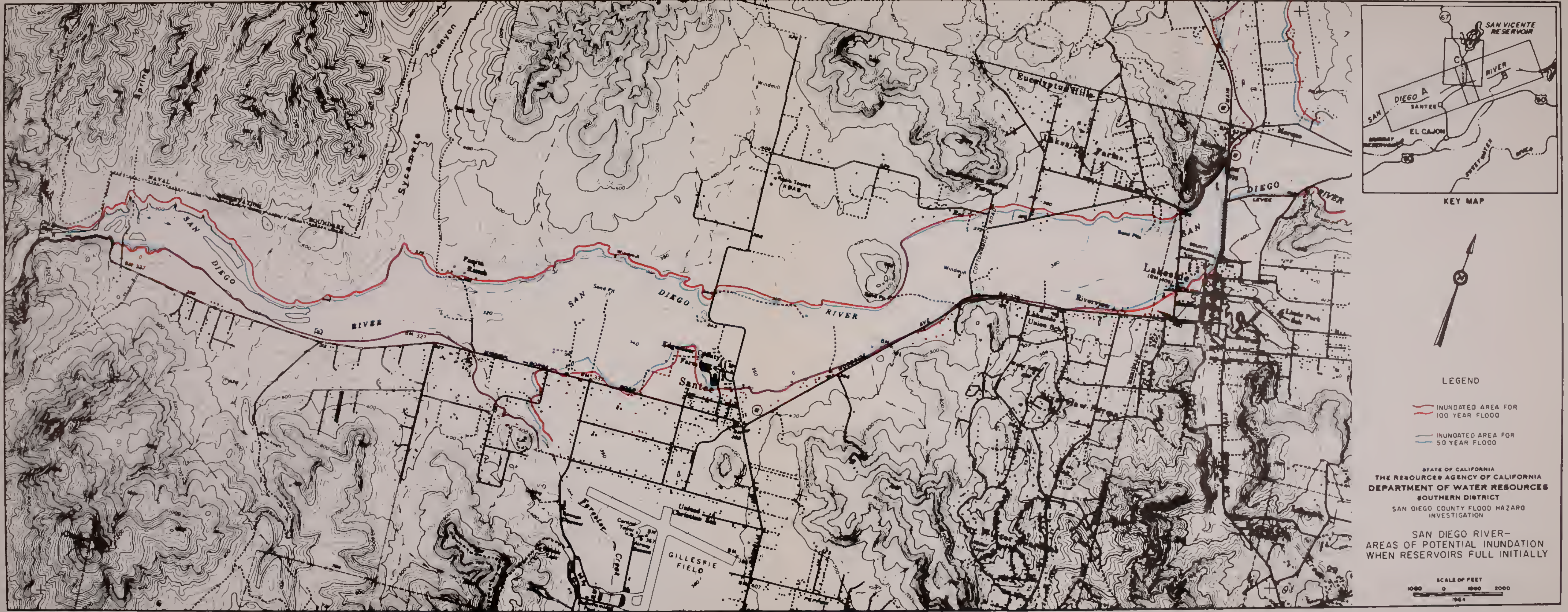
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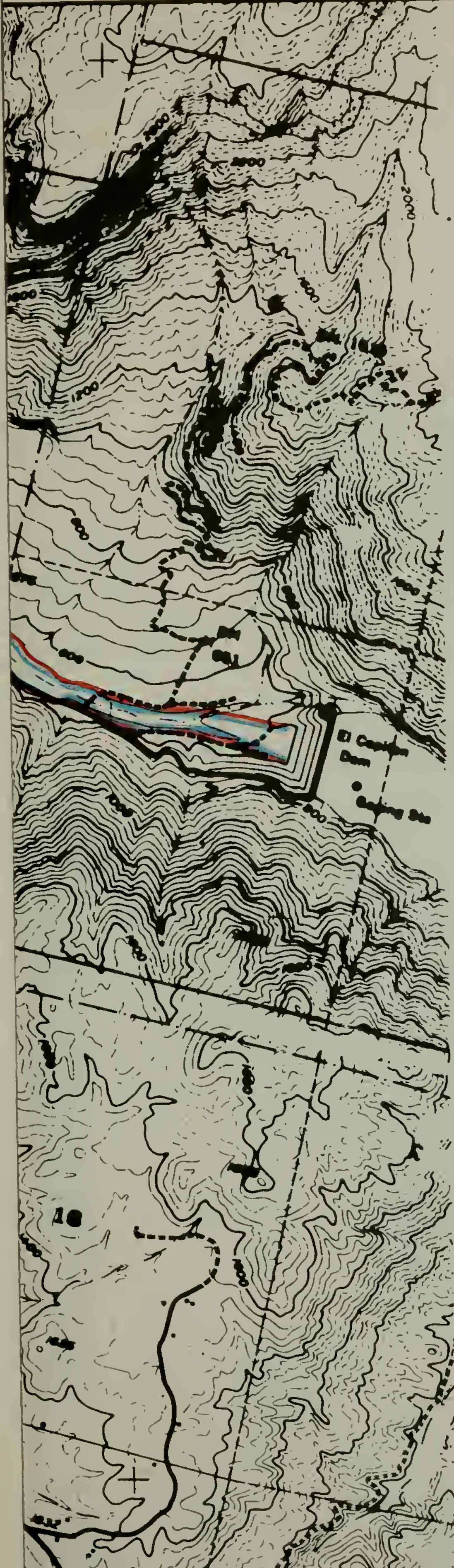

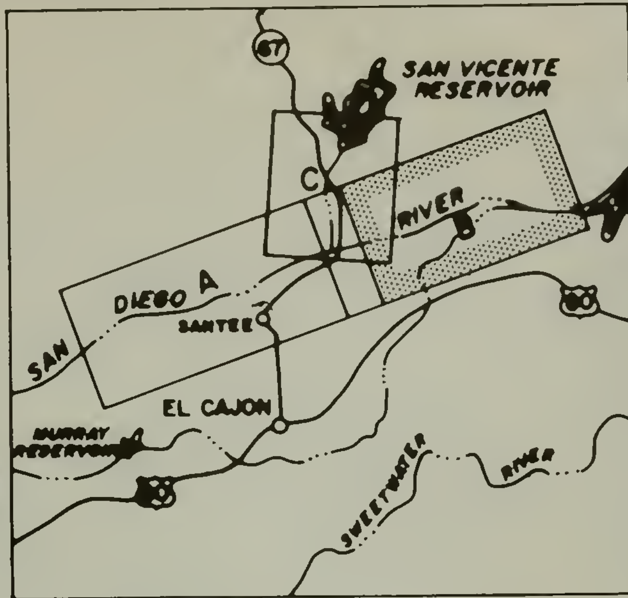

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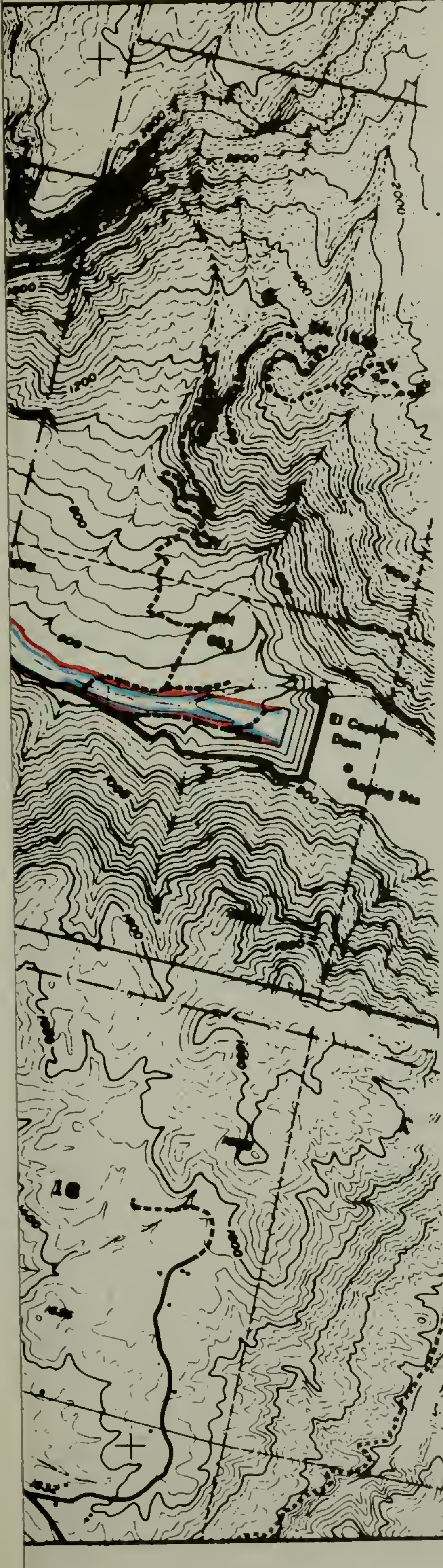

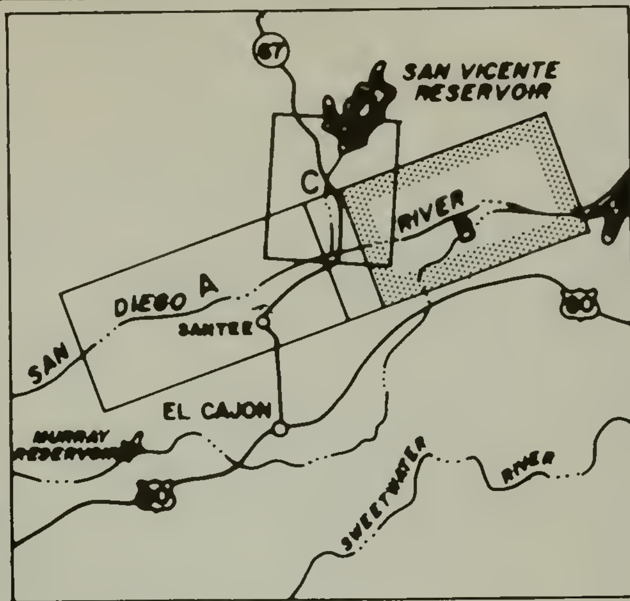

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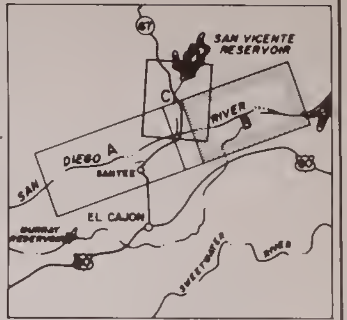

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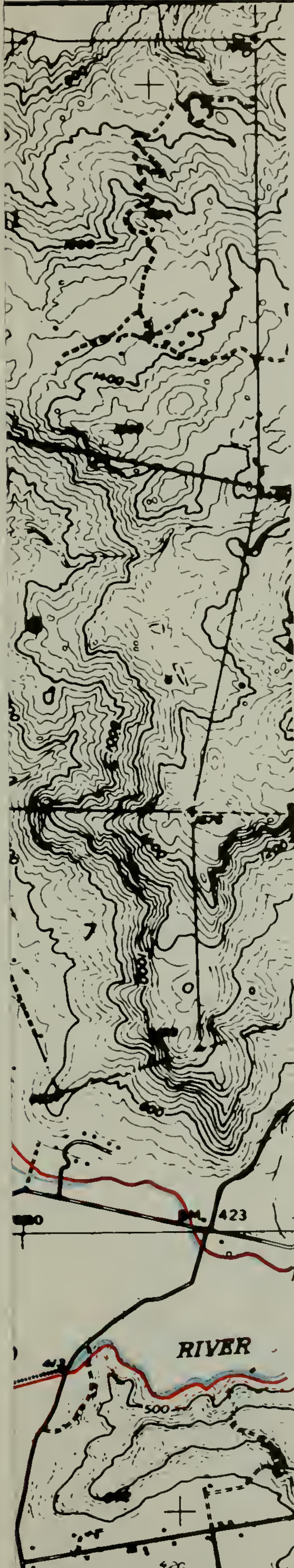

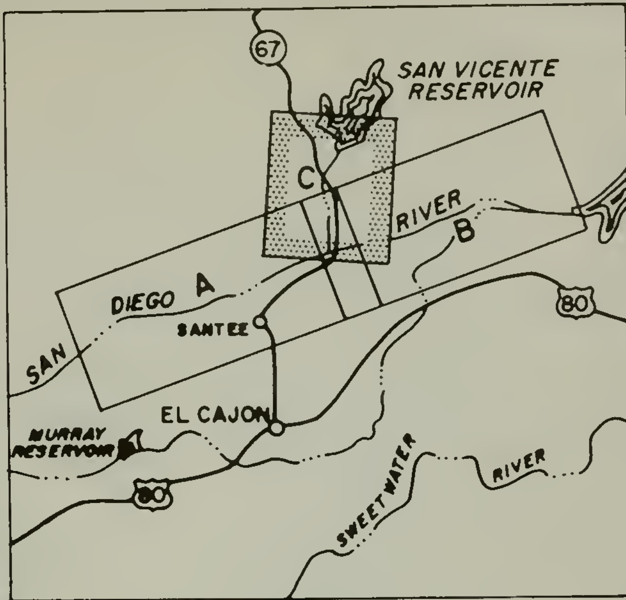

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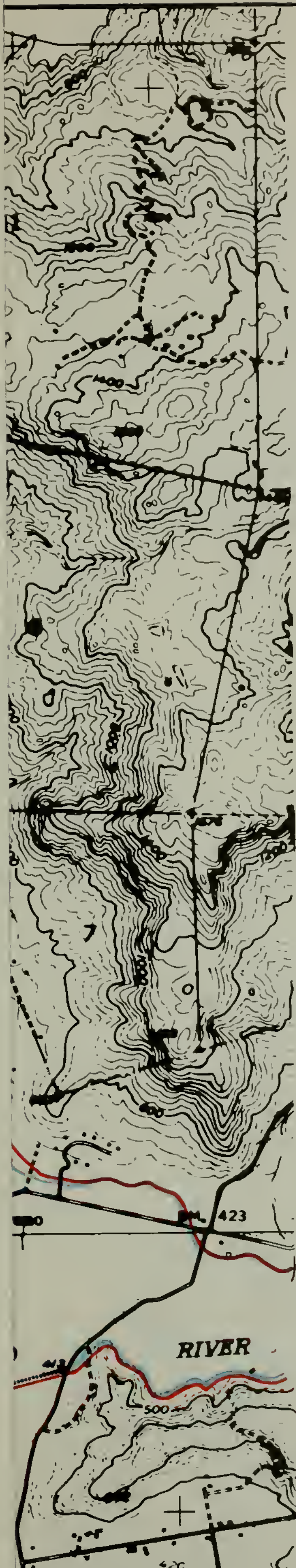

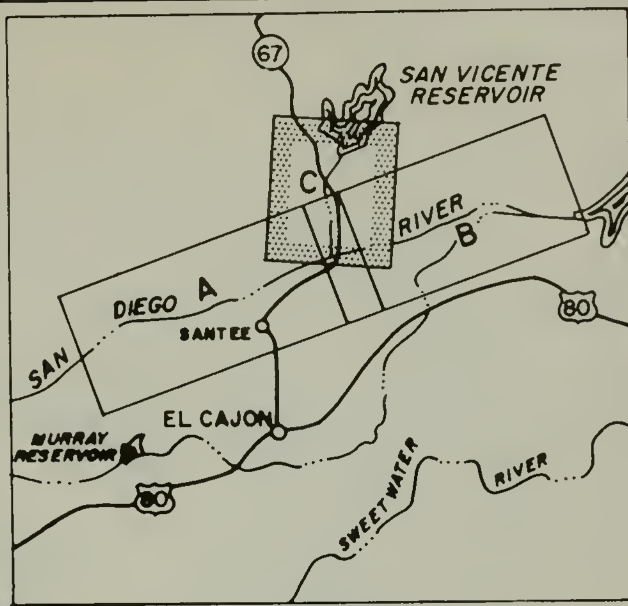

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INUNDATED AREA FOR 100 YEAR FLOOD

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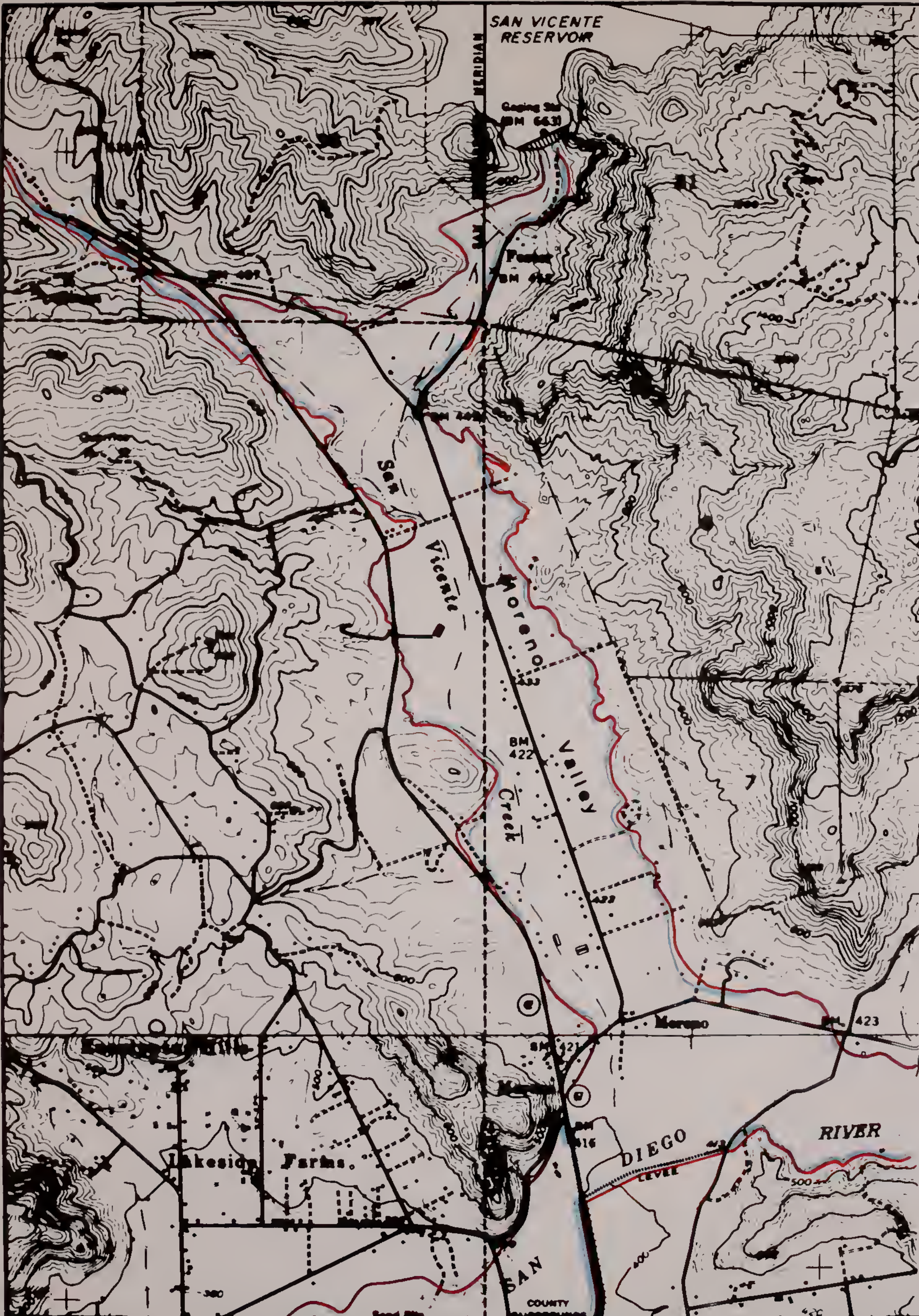

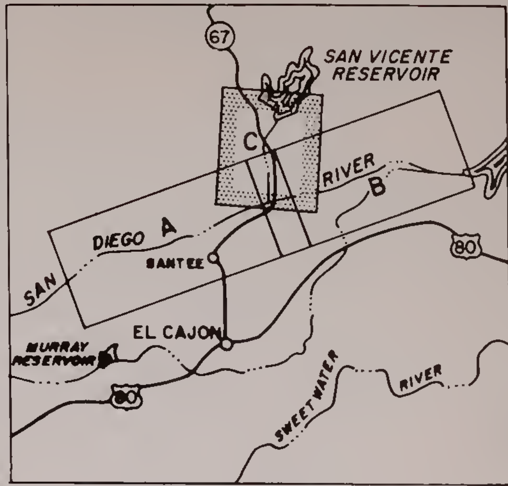

KEY MAP

LEGEND

INUNDATED AREA FOR 100 YEAR FLOOD

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APPENDIX D

SWEETWATER RIVER - AREAS OF POTENTIAL INUNDATION

APPENDIX D

SWEETWATER RIVER - AREAS OF POTENTIAL INUNDATION

APPENDIX D

SWEETWATER RIVER -
AREAS OF POTENTIAL INUNDATION

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(Plates follow text of Appendix)

CHAPTER I. INTRODUCTION

In this appendix are presented magnitudes of peak flood flows at selected stations along the Sweetwater River between Sweetwater Dam and the river mouth for floods having a 50- and 100-year recurrence interval. Areas inundated by these floods are shown on plates at the end of the appendix.

The methodology utilized in this appendix for reservoir and stream channel flood routing and for backwater computations follows commonly used techniques as detailed in Appendix B. Water-surface profiles thus determined were plotted on maps to indicate the areas of potential inundation.

Scope of Investigation

The studies of the flood potential of the Sweetwater River were directed toward producing reliable estimates of water-surface profiles for flood peaks of 50- and 100-year recurrence intervals, and to delineate the areas which might be inundated by these floods. The work necessary to accomplish these objectives consisted of establishing reliable estimates of peak flood flows, determining hydraulic properties of the flood channels at selected intervals, calculating water-surface profiles along the approximately eight miles of floodplain from Sweetwater Dam to the river mouth, and delineating areas of potential inundation.

Description of Area of Investigation

The Sweetwater River watershed has an area of 230 square miles and lies on the western slopes of the Coast Range in San Diego County. The river flows generally southwesterly and discharges into the Pacific

Ocean through San Diego Bay. Its length is approximately 45 miles, two-thirds of which lies in the higher elevations above the community of Jamacha.

The upper portion of the Sweetwater River Basin becomes more rugged at higher elevations, but the lower portion of the basin consists of high mesa lands and valleys. Elevations throughout the basin range from sea level to about 600 feet in the lower portion and from about 600 to 6,500 feet in the mountains. Cuyamaca Peak, the highest point in the basin, has an elevation of 6,515 feet. The mean normal precipitation varies from approximately 11 inches in the lower portion to approximately 35 inches in the mountains. The extremes of discharge into Sweetwater Reservoir have varied from no discharge to 45,500 cubic feet per second during the flood of January 1916.

There are two major reservoirs, Sweetwater Reservoir and Lake Loveland, within the Sweetwater River watershed. Sweetwater Reservoir on the Sweetwater River, approximately eight miles upstream from the river mouth, with a capacity of 27,689 acre-feet, is used to store both local runoff and water imported from the Colorado River through both the First and Second San Diego Aqueducts for municipal, industrial, and irrigation use. Lake Loveland, also on the Sweetwater River, approximately 15 miles upstream from Sweetwater Dam, has a capacity of 27,700 acre-feet and is used for storage of local water for municipal, industrial, and irrigation purposes. Both reservoirs are owned and operated by the California Water and Telephone Company. Data pertinent to these reservoirs are listed in Table 1.

TABLE 1

RESERVOIRS WITHIN THE SWEETWATER RIVER WATERSHED*

Name of dam	Owner	Stream	Height of dam above original streambed, in feet	Storage capacity, in acre-feet	Area of reservoir, in acres**	Drainage area, in square miles	Use
Lake Loveland	California Water and Telephone Company	Sweetwater River	198	27,700	475	98	Storage and diversion of local water for municipal, industrial, and irrigation use.
Sweetwater	California Water and Telephone Company	Sweetwater River	108	27,689	936	182	Storage and diversion of local and imported water for municipal, industrial, and irrigation use.

*Data from Department of Water Resources Bulletin No. 17, "Dams Within Jurisdiction of the State of California"

**Area at spillway crest elevation

That portion of the Sweetwater River Basin considered for potential flood hazards is located between Sweetwater Dam and the mouth of the river. The City of Chula Vista and the community of Spring Valley lie within the study area. The Sweetwater River Basin and the area within the basin studied for possible inundation are delineated on Plate D-1, "Boundaries of Investigational Area and Tributary Drainage Basin for Sweetwater River."

CHAPTER II. PEAK FLOOD FLOWS

Determination of peak flood flows at the 50- and 100-year frequency level for ungaged reaches of the Sweetwater River and its tributaries is discussed in this chapter. The method outlined herein combines the use of regression equations and techniques of reservoir and river channel flood routing. The development of the equations was discussed in detail in Appendix A, "Regional Flood Frequency Analysis," and the routing techniques utilized are explained in Appendix B, "Methods and Procedures."

Determination of Flood Discharges from Ungaged Areas

The estimated peak discharges at selected ungaged points on the Sweetwater River as a result of runoff emanating from areas below Sweetwater Dam for floods of 50- and 100-year recurrence intervals are presented in Table 2. These values of discharge were determined by use of Figures B-1 and B-2 in Appendix B.

The estimated unimpaired peak flood discharges from areas above Lake Loveland and the areas between Lake Loveland and Sweetwater Reservoir were determined in the same manner as for the areas below Sweetwater Dam. The estimated 50- and 100-year flood peaks for the 100-square-mile drainage area above Lake Loveland were found to be 21,200 and 30,000 cubic feet per second, respectively. The estimated unimpaired 50- and 100-year flood peaks for the 81-square-mile drainage area between Lake Loveland and Sweetwater Reservoir were found to be 17,800 and 25,000 cubic feet per second, respectively.

The shape of the flood hydrograph characterized by these peaks is shown on Figure B-3 and is discussed further in Appendix B.

TABLE 2

ESTIMATED PEAK FLOOD DISCHARGES FROM AREAS BELOW SWEETWATER RESERVOIR FOR SELECTED LOCATIONS ON THE SWEETWATER RIVER

Location	Drainage area, in square miles[a]	Diameter of circle of equivalent area, in miles	Basin length, in miles	Shape factor Sh	Peak discharge, in cubic feet per second	
					50-year flood	100-year flood
At U. S. Highway 101 Bridge	35.4	6.7	13.4	0.50	11,200	15,700
Approx. 800 feet upstream from intersection of Valley Road and Sweetwater Road	30.7	6.3	11.3	0.55	9,800	13,700
Confluence of Rice Canyon and Sweetwater River	25.5	5.7	10.6	0.54	8,900	12,500
Approx. 700 feet upstream from intersection of Bonita Road and Otay Lakes Road	20.6	5.1	8.0	0.64	7,200	9,800
Approx. 2,100 feet downstream from Sweetwater Dam	10.8	3.7	6.0	0.62	5,100	7,000

a. Excludes 181 square miles of drainage area above Sweetwater Reservoir

The flood peaks obtained from Figures B-1 and B-2 in Appendix B are attenuated by storage capacity available in the reservoirs, as well as channel storage, and the resulting diminished outflows were combined with the values shown in Table 2 to determine the total discharge at various points.

Effect of Reservoir and Channel Storage on Peak Flood Flows

This section shows the attenuating effect of reservoir and channel storage on peak flood flows. The diminishing of flood peaks as a result of flood flows entering reservoir storage will be discussed first, followed by a description of the effect of channels on flood peaks.

Reservoir Flood Routing

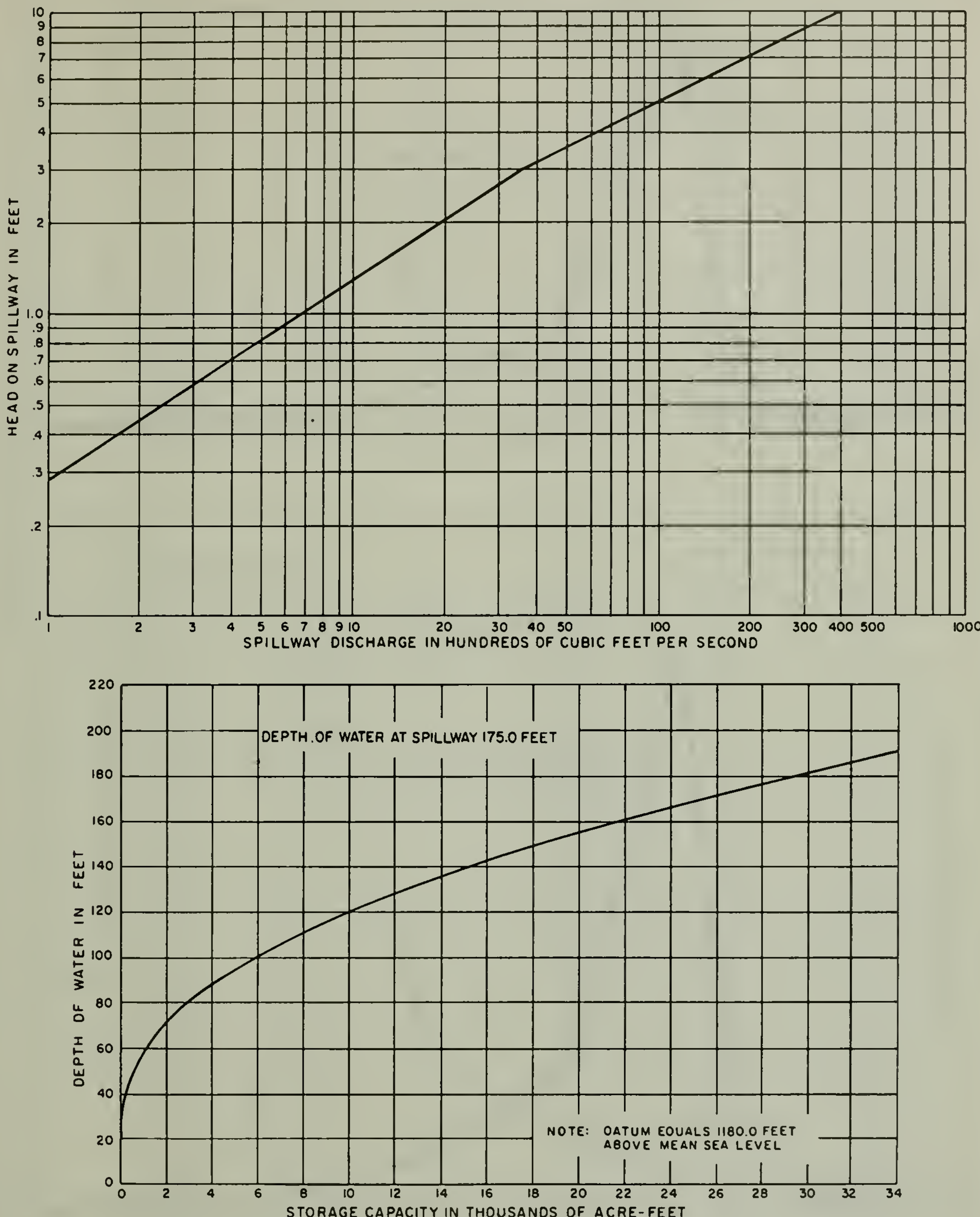
The unimpaired floods for the drainage area above Lake Loveland were first routed through Lake Loveland. Then, the combined hydrographs, consisting of the routed hydrographs of the overflows from Lake Loveland and the hydrographs of the unimpaired flows from the contributing area between Lake Loveland and Sweetwater Reservoirs for 50- and 100-year frequency intervals, were routed through Sweetwater Reservoir. Two initial reservoir conditions were assumed: (1) Sweetwater and Lake Loveland Reservoirs one-half full, and (2) both reservoirs full.

Lake Loveland. Utilizing the storage capacity curve and the spillway discharge curve for Lake Loveland as shown on Figure D-1, flood flows for the 50- and 100-year recurrence intervals were routed through the reservoir. As stated, this was done assuming two initial reservoir conditions: one-half full (13,850 acre-feet) and full (27,700 acre-feet).

With the reservoir full initially, the flood peaks for the inflow and outflow hydrographs at the 100-year recurrence interval are approximately 30,000 and 28,950 cubic feet per second, respectively, with a lag of about one hour between the peaks. At the 50-year flood recurrence interval, the flood peaks are approximately 21,200 and 20,450 cubic feet per second, respectively, with a lag of about one hour between the peaks. The results of routing the flood flows with the reservoir full initially are presented on Figure D-2.

With the reservoir assumed to be one-half full initially, the flood peaks for the inflow and outflow hydrographs at the 100-year recurrence interval are approximately 30,000 and 24,900 cubic feet per second, respectively, with a lag of about four hours between the peaks. At the 50-year recurrence interval, the flood peaks are approximately 21,200 and 15,000 cubic feet per second for the inflow and outflow hydrographs, respectively, with a lag of about six hours between the peaks. The results of routing with the reservoir one-half full initially are depicted graphically on Figure D-3.

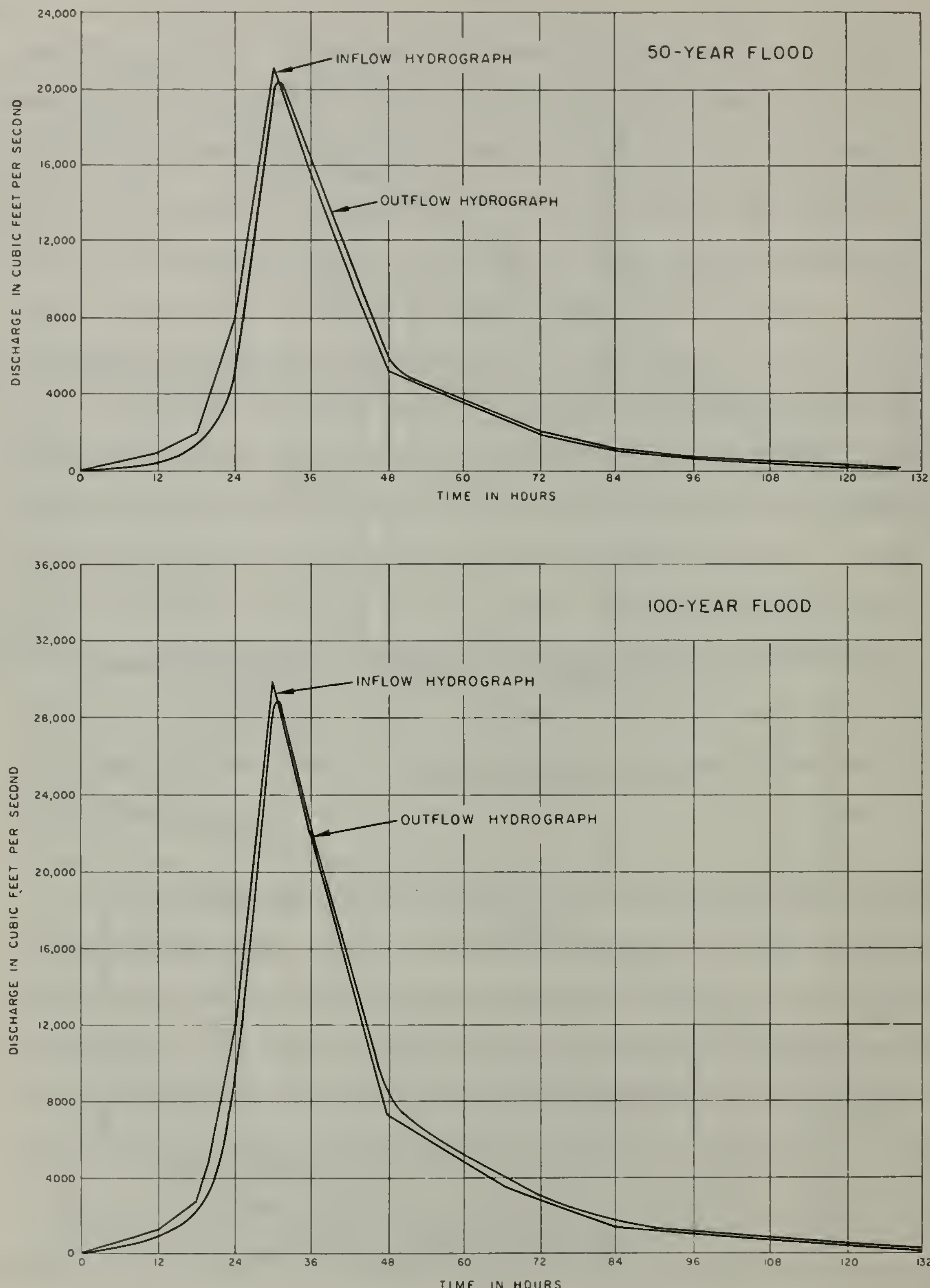
Sweetwater Reservoir. Utilizing the storage capacity curve and the spillway discharge curve for Sweetwater Reservoir as shown on Figure D-4, flood flows at the 50- and 100-year recurrence intervals were routed through the reservoir. The routed flood flows are the combined hydrograph of the routed overflows from Lake Loveland and the hydrographs of the contributing areas between Lake Loveland and Sweetwater Reservoirs. Routing was based on two initial storage conditions at Sweetwater Reservoir: one-half full (13,850 acre-feet) and full (27,700 acre-feet).



SPILLWAY DISCHARGE AND STORAGE CAPACITY CURVES FOR LAKE LOVELAND

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

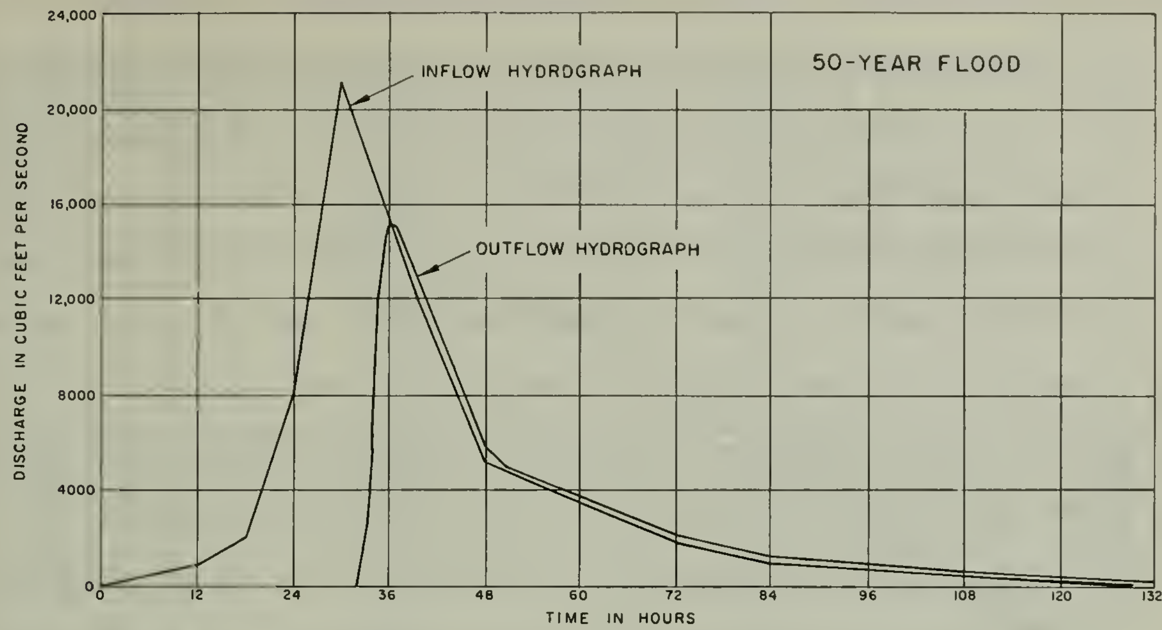
FIGURE D-2

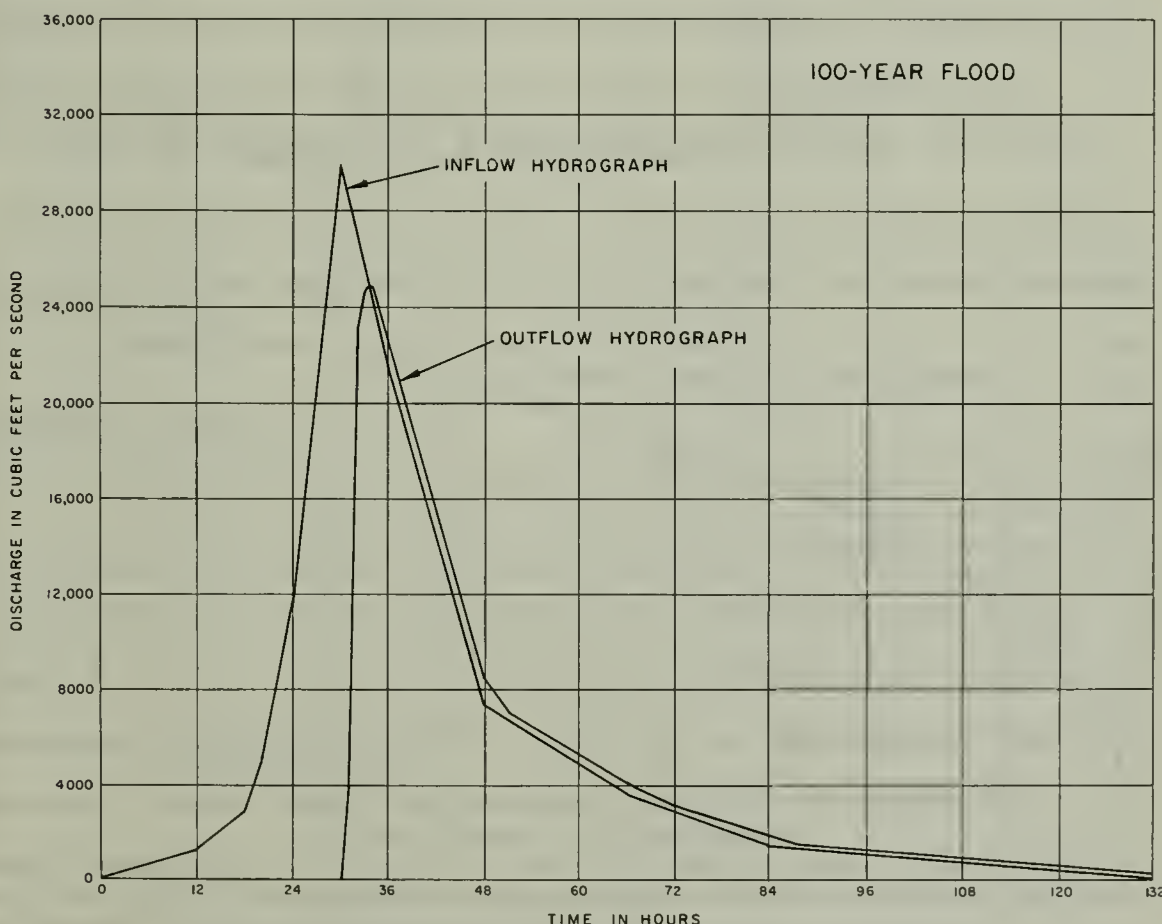


INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT LAKE LOVELAND

ASSUMING FULL RESERVOIR CONDITIONS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

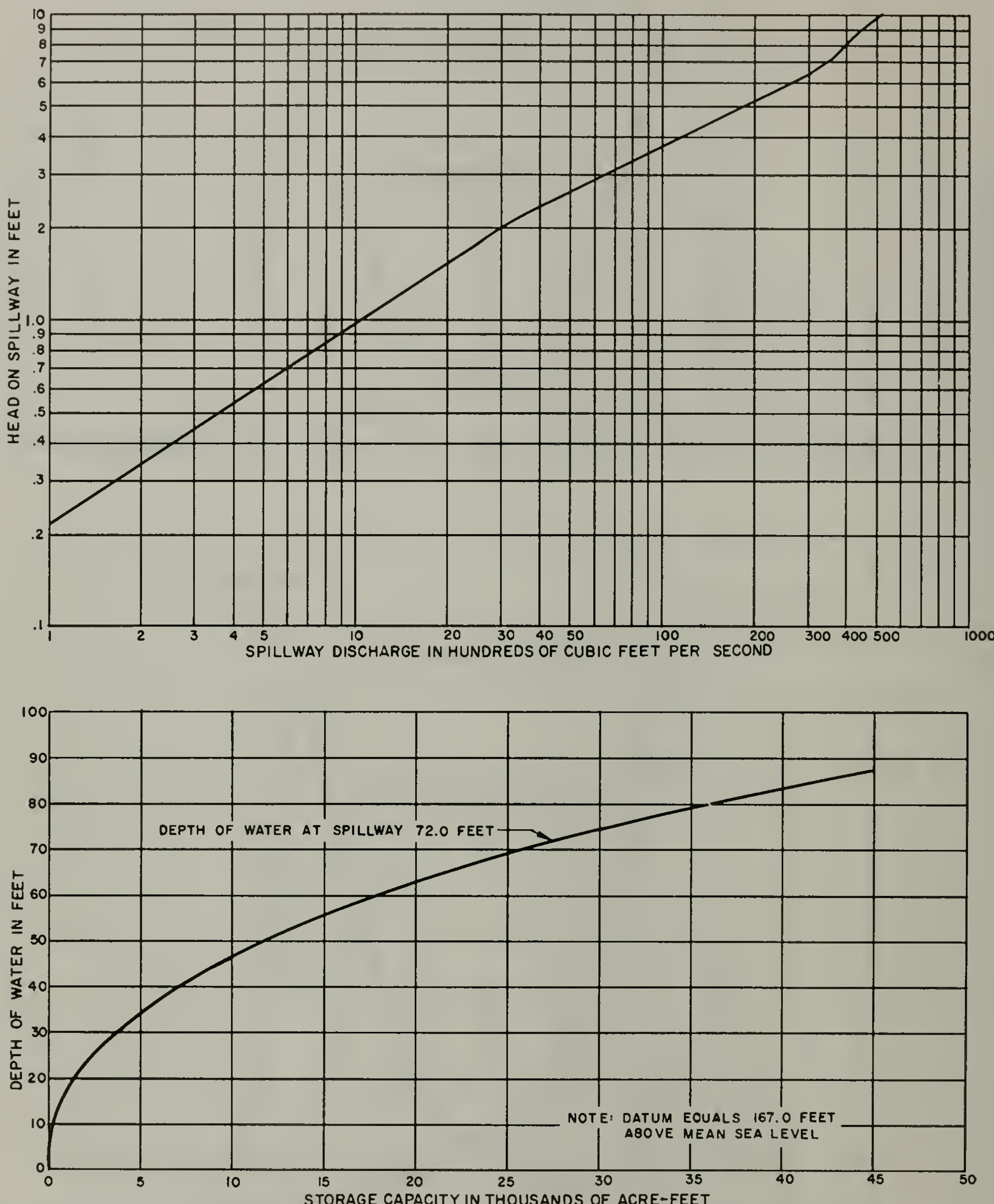




INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT LAKE LOVELAND
ASSUMING HALF-FULL RESERVOIR CONDITIONS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

FIGURE D-4



SPILLWAY DISCHARGE AND STORAGE CAPACITY CURVES FOR SWEETWATER RESERVOIR

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1984

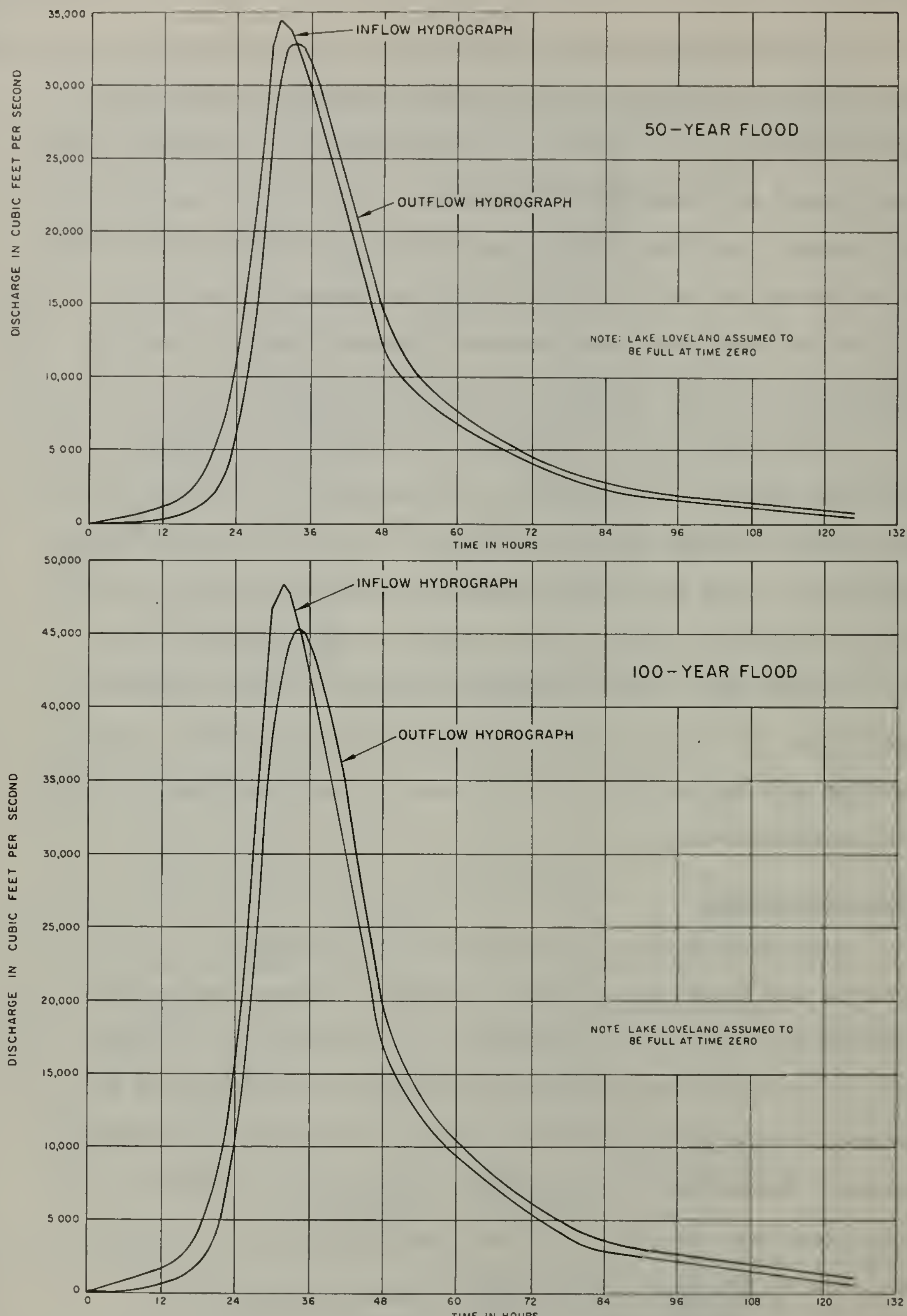
With the reservoir full initially, the flood peaks for the inflow and outflow hydrographs at the 100-year recurrence interval are approximately 48,500 and 45,300 cubic feet per second, respectively, with a lag of about two hours between the peaks. At the 50-year flood recurrence interval, the flood peaks are approximately 34,500 and 33,000 cubic feet per second for the inflow and outflow hydrographs, respectively, with a lag of about three hours between the peaks. Results of routing with the reservoir full initially are presented on Figure D-5.

With the reservoir assumed to be one-half full initially, the flood peaks for the inflow and outflow hydrographs at the 100-year recurrence interval are approximately 38,800 and 35,800 cubic feet per second, respectively, with a lag of about three hours between the peaks. At the 50-year recurrence interval, the flood peaks are approximately 24,100 and 20,000 cubic feet per second for the inflow and outflow hydrographs, respectively, with a lag of about four hours between the peaks. Results of routing with the reservoir one-half full initially are depicted graphically on Figure D-6.

Stream Flood Routing

By utilization of the method described in Appendix B, the outflows from Lake Loveland were routed downstream to Sweetwater Reservoir. The hydrographs of the routed discharges were combined with the hydrographs of the floods from contributing areas between Lake Loveland and Sweetwater Reservoirs to determine the inflow hydrographs to Sweetwater Reservoir. The outflows from Sweetwater Reservoir were routed downstream, considering the flows from the contributing areas, to develop hydrographs at the mouth of the river.

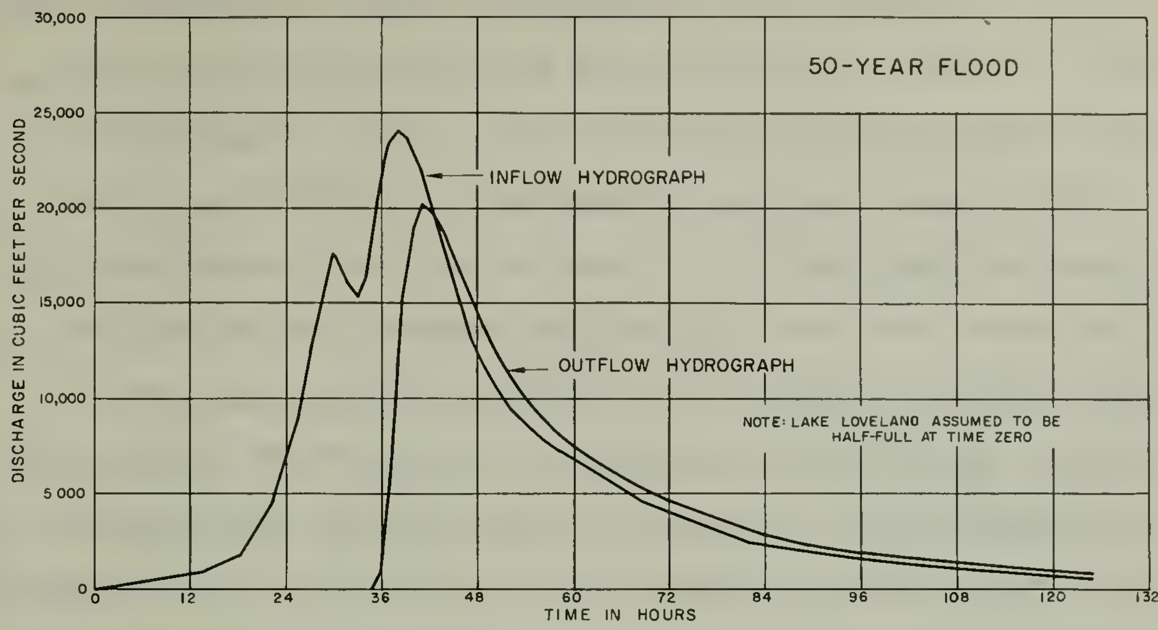
FIGURE D-5

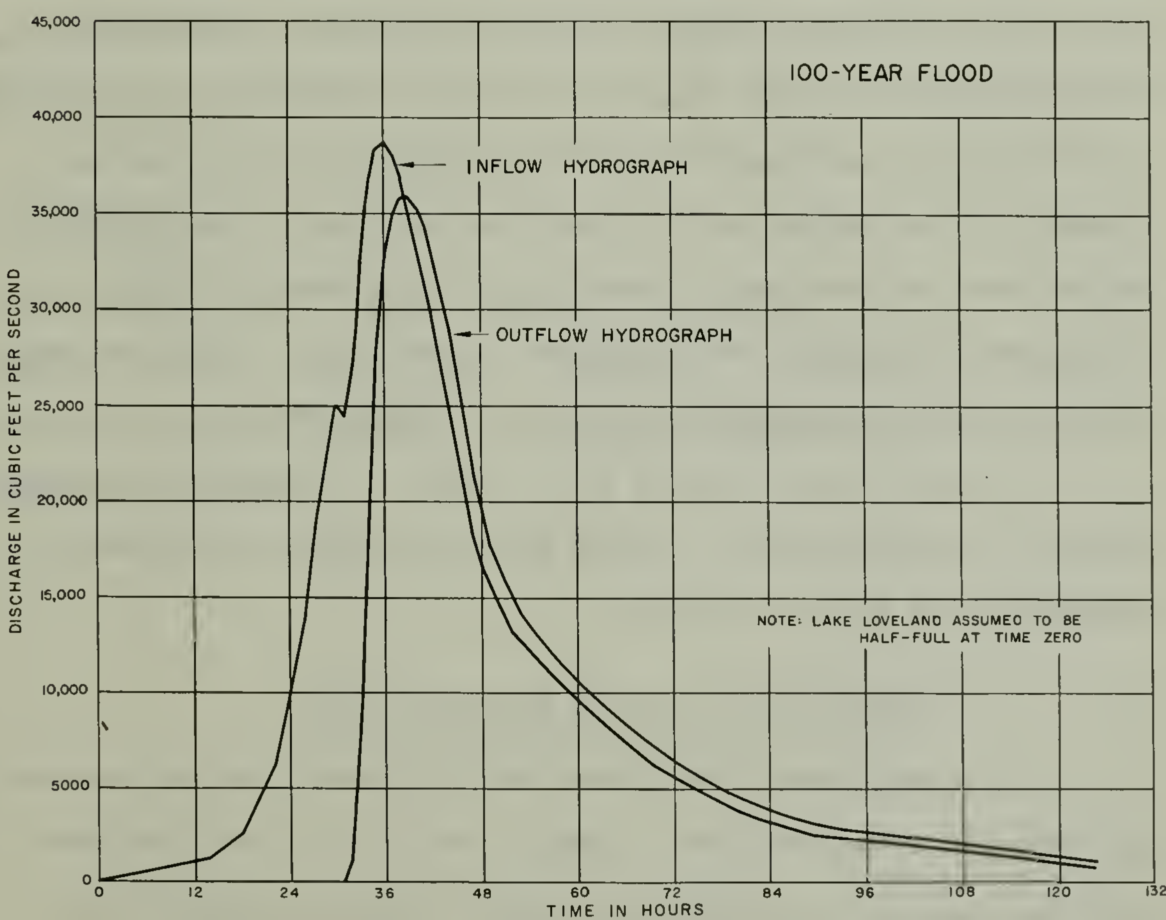


INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT SWEETWATER RESERVOIR

ASSUMING FULL RESERVOIR CONDITIONS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964





INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT SWEETWATER RESERVOIR
ASSUMING HALF-FULL RESERVOIR CONDITIONS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

The travel time, T, between Lake Loveland and Sweetwater Reservoir was estimated by calculating the weighted mean velocity for the entire reach, as described following. As an initial step, three representative cross sections were selected for the reach between the two reservoirs. The normal depth and mean velocity were computed at each cross section based upon a 100-year peak discharge, average bed slope, and a value of 0.035 for n, the roughness coefficient in the Manning equation. The computed mean velocities were then weighted according to the estimated length of the reach represented by each cross section. The average of the weighted velocities, 13.4 feet per second, was used to estimate the value of the travel time, T, with a resulting value of two hours for T. The travel time, T, for the reach between Sweetwater Dam and the mouth of the river was also determined by estimating the velocity of the flood wave. The velocity of the flood wave for the reach was assumed to be the average of the velocities determined in the backwater computations, as discussed in Appendix B, for discharges of 55,000, 45,000, and 30,000 cubic feet per second. A velocity of eight feet per second was used with a resulting value of 1.4 hours for T.

By utilizing a value of T of 1.4 hours in Equation 7 of Appendix B and a routing period, t, of one hour, the outflow hydrographs were generated at the mouth of the river.

Determination of Total Peak Flood Flows

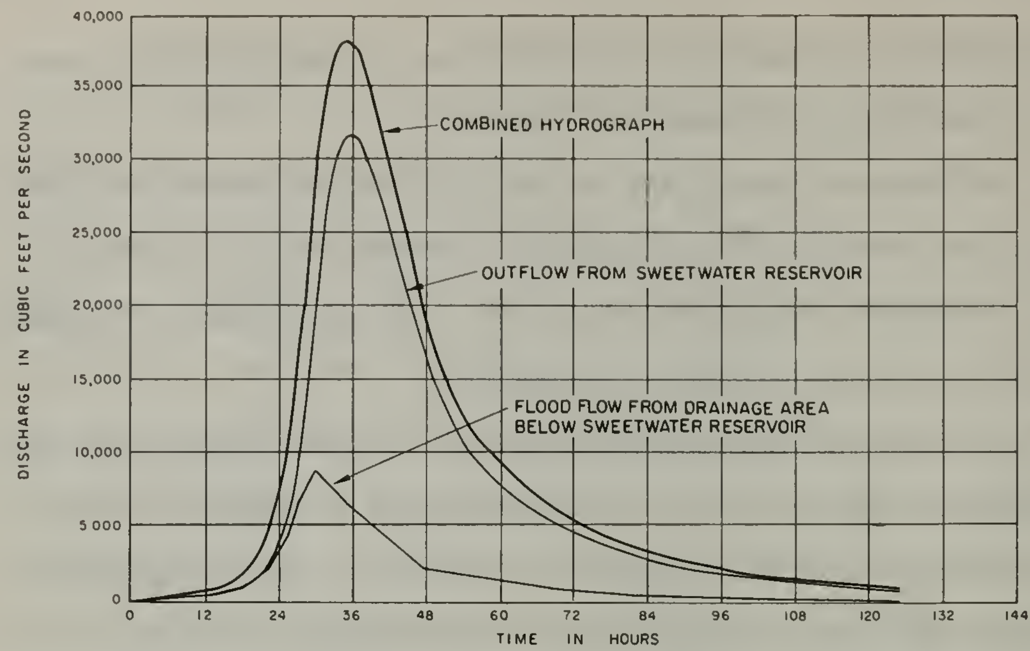
The peak flood flows at each selected point along the reach of the Sweetwater River under study, namely, that portion downstream from Sweetwater Dam, were determined by combining flood hydrographs of the routed overflows from Sweetwater Reservoir with the hydrographs of flows from the contributing area below the reservoir.

The combined hydrographs for 50- and 100-year floods, with reservoirs initially full, at the confluence of Sweetwater River and Rice Canyon, are depicted on Figures D-7 and D-8. The hydrographs at the mouth of the river are shown on Figures D-9 and D-10.

The combined hydrographs for 50- and 100-year floods, with reservoirs one-half full initially, at the confluence of Sweetwater River and Rice Canyon, are shown on Figures D-11 and D-12. The hydrographs at the mouth of the river are illustrated on Figures D-13 and D-14.

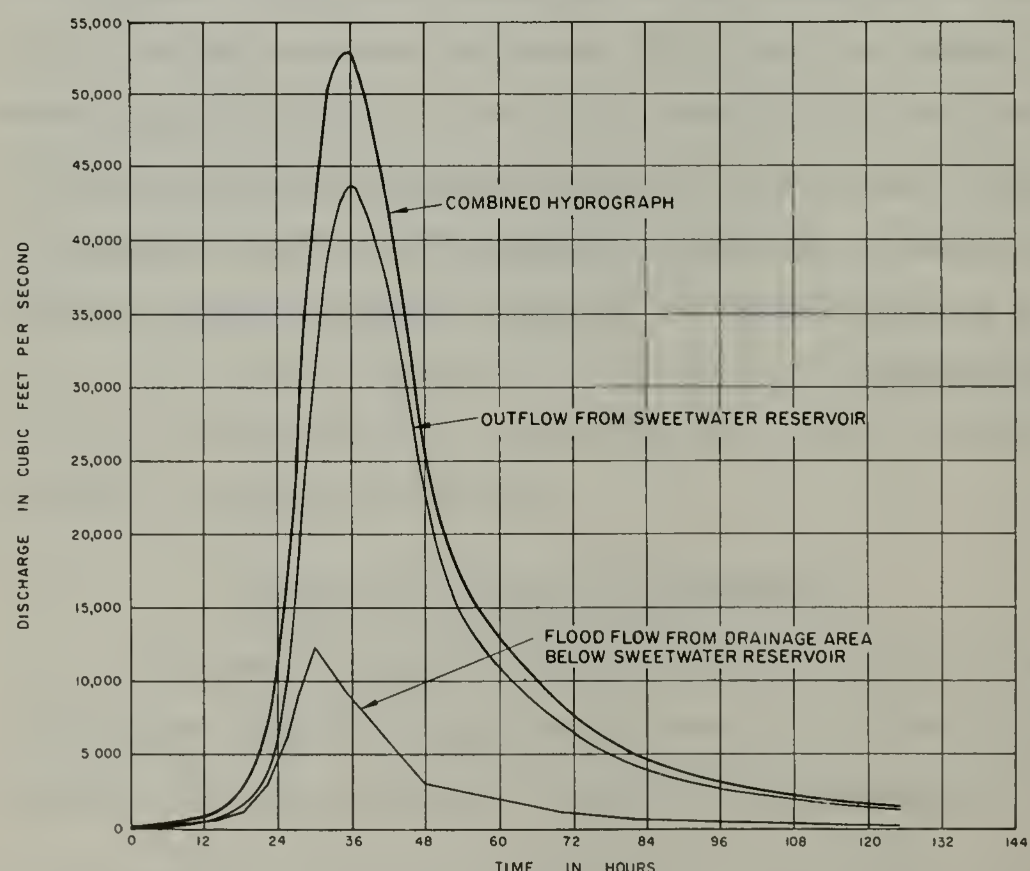
In Tables 3 and 4, the peak discharges are summarized for 50- and 100-year floods at selected locations along the Sweetwater River downstream from Sweetwater Dam for the assumed condition of reservoirs full and one-half full initially. It will be noted that the partial discharges tabulated for each area contributing to the peak discharge are the discharges taken from the individual hydrographs directly below the maximum discharge on the combined hydrograph, and that this value may not be the maximum discharge for the smaller hydrographs due to the influence of lag time.

FIGURE D-7



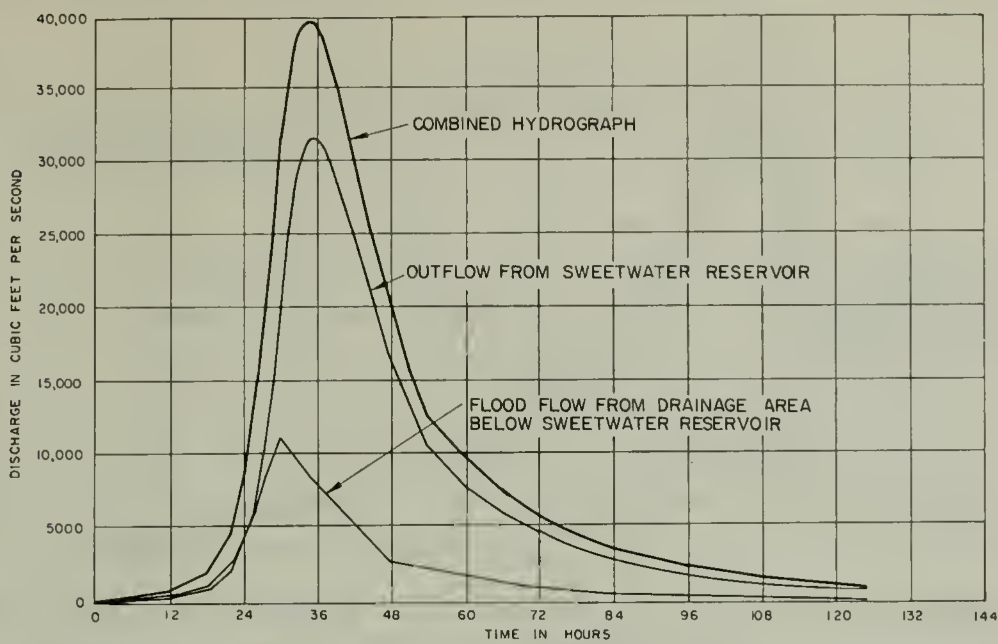
FLOOD HYDROGRAPH AT CONFLUENCE OF SWEETWATER RIVER
AND RICE CANYON FOR 50-YEAR FLOOD
ASSUMING FULL RESERVOIR CONDITIONS

FIGURE D-8



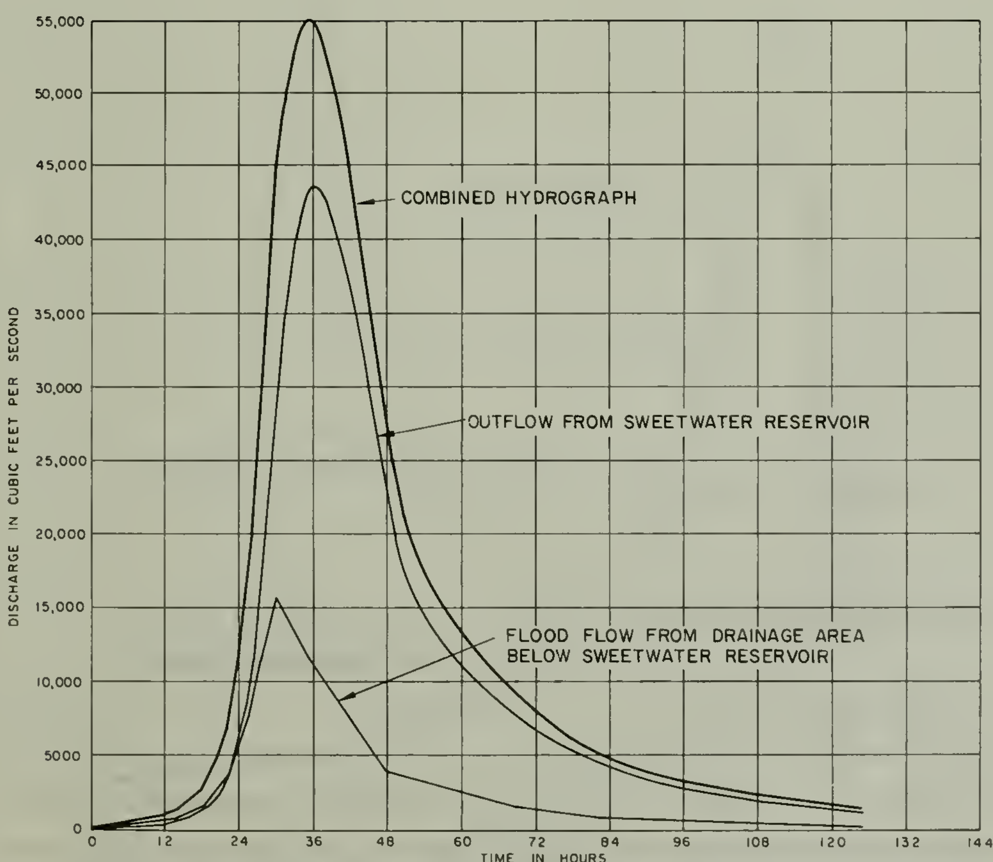
FLOOD HYDROGRAPH AT CONFLUENCE OF SWEETWATER RIVER
AND RICE CANYON FOR 100-YEAR FLOOD
ASSUMING FULL RESERVOIR CONDITIONS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964



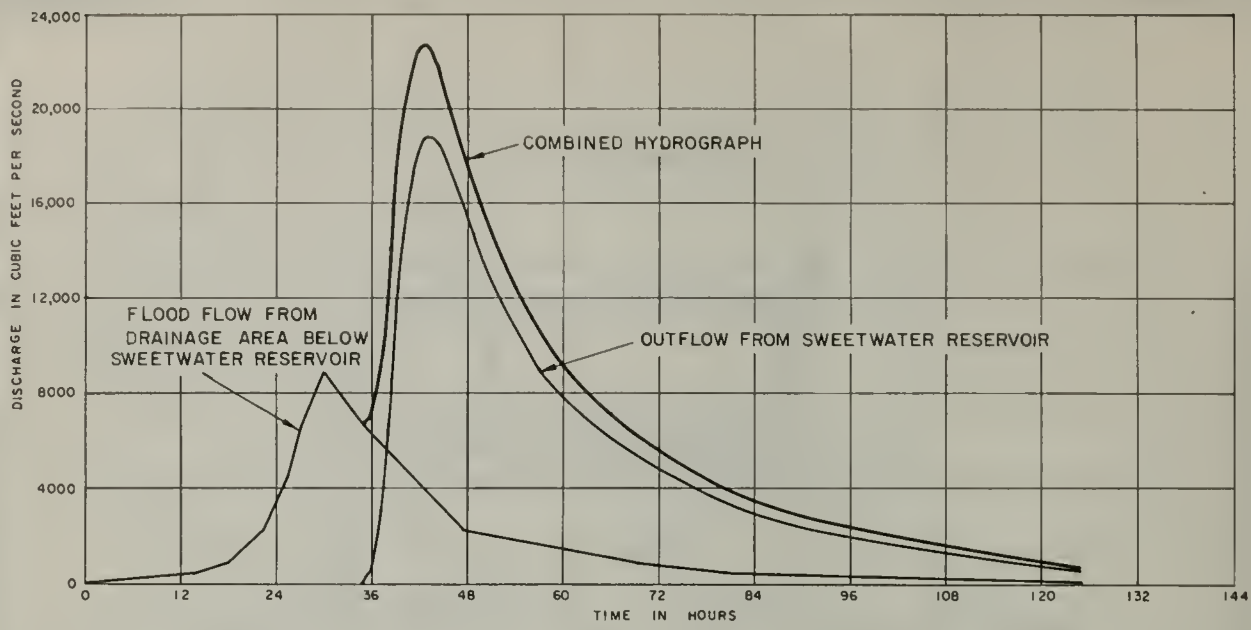
FLOOD HYDROGRAPH AT MOUTH OF SWEETWATER RIVER
FOR 50-YEAR FLOOD
ASSUMING FULL RESERVOIR CONDITIONS

FIGURE D-10



FLOOD HYDROGRAPH AT MOUTH OF SWEETWATER RIVER
FOR 100-YEAR FLOOD
ASSUMING FULL RESERVOIR CONDITIONS

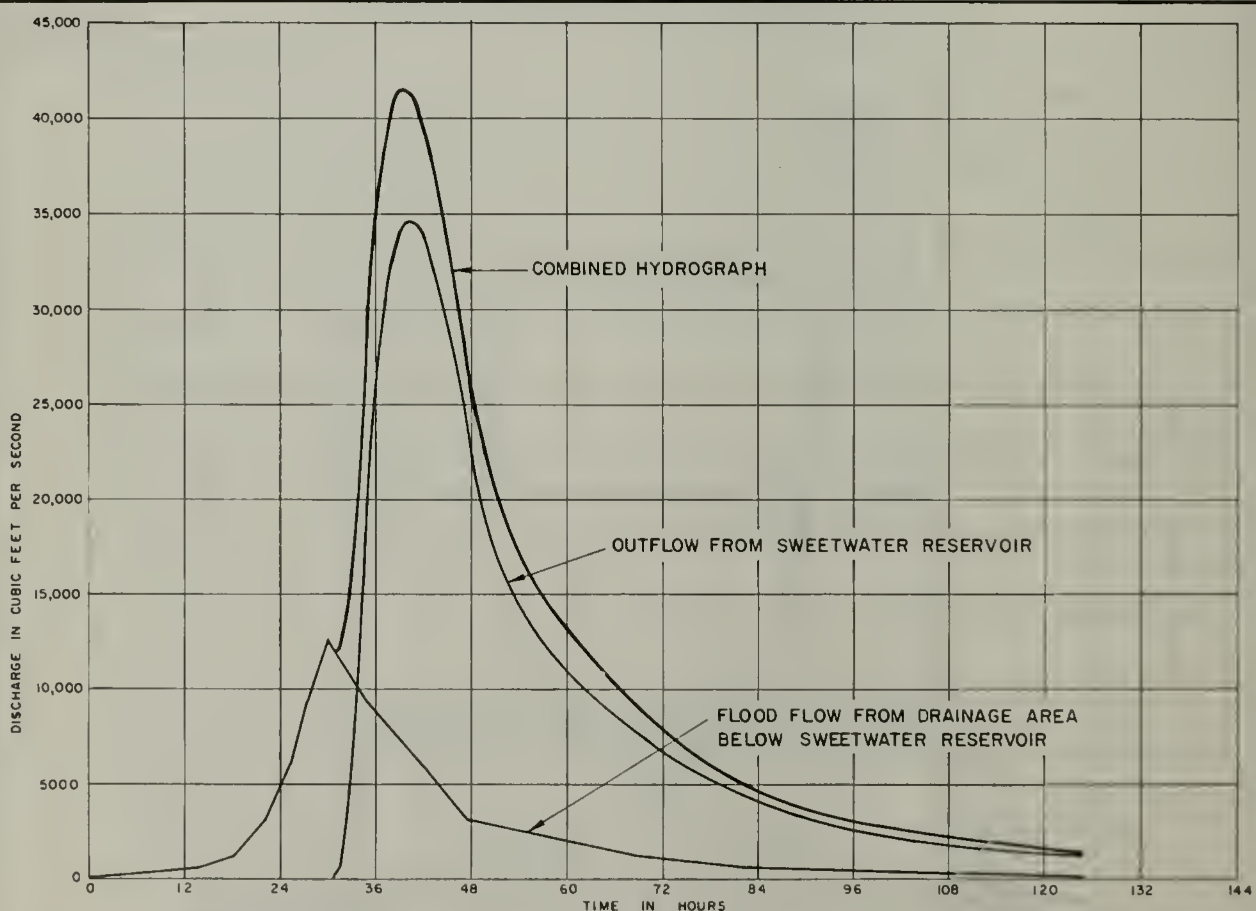
FIGURE D-11



FLOOD HYDROGRAPH AT CONFLUENCE OF SWEETWATER RIVER AND RICE CANYON FOR 50-YEAR FLOOD

ASSUMING HALF-FULL RESERVOIR CONDITIONS

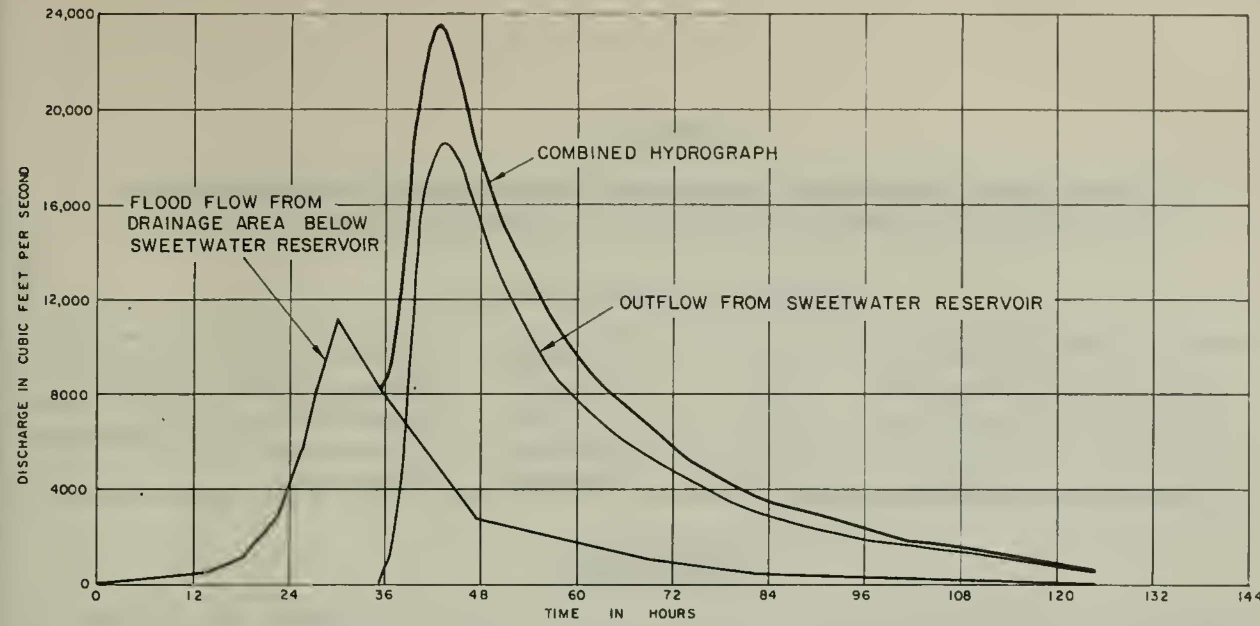
FIGURE D-12



FLOOD HYDROGRAPH AT CONFLUENCE OF SWEETWATER RIVER AND RICE CANYON FOR 100-YEAR FLOOD

ASSUMING HALF-FULL RESERVOIR CONDITIONS

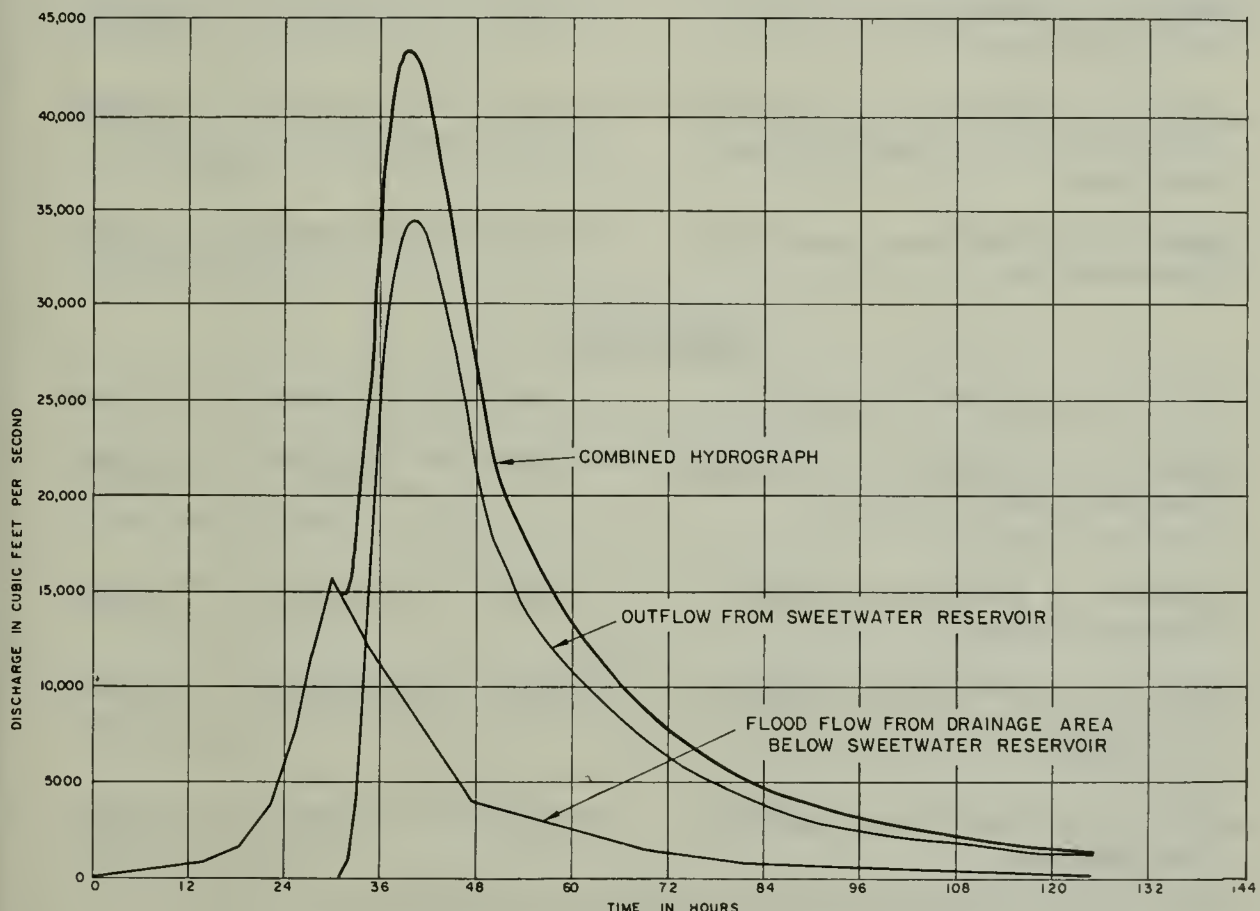
DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964



FLOOD HYDROGRAPH AT MOUTH OF SWEETWATER RIVER
FOR 50-YEAR FLOOD

ASSUMING HALF-FULL RESERVOIR CONDITIONS

FIGURE D-14



FLOOD HYDROGRAPH AT MOUTH OF SWEETWATER RIVER
FOR 100-YEAR FLOOD

ASSUMING HALF-FULL RESERVOIR CONDITIONS

TABLE 3

ESTIMATED TOTAL PEAK FLOOD DISCHARGES FOR SELECTED LOCATIONS ON THE SWEETWATER RIVER, ASSUMING FULL RESERVOIR CONDITIONS

In cubic feet per second

Location	Routed spills from Sweetwater Reservoir	Flood discharges from area below Sweetwater Reservoir	Total peak discharges
	50-year Flood		
At U. S. Highway 101 Bridge	31,200	8,800	40,000
Approx. 800 feet upstream from intersection of Valley Road and Sweetwater Road	31,700	7,300	39,000
Confluence of Rice Canyon and Sweetwater River	31,700	6,600	38,300
Approx. 700 feet upstream from intersection of Bonita Road and Otay Lakes Road	31,700	5,400	37,100
Approx. 2,100 feet downstream from Sweetwater Dam	31,700	3,700	35,400
	100-year Flood		
At U. S. Highway 101 Bridge	43,200	11,800	55,000
Approx. 800 feet upstream from intersection of Valley Road and Sweetwater Road	43,400	10,300	53,700
Confluence of Rice Canyon and Sweetwater River	43,600	9,600	53,200
Approx. 700 feet upstream from intersection of Bonita Road and Otay Lakes Road	43,800	7,000	50,800
Approx. 2,100 feet downstream from Sweetwater Dam	43,800	5,000	48,800

TABLE 4

ESTIMATED TOTAL PEAK FLOOD DISCHARGES FOR SELECTED LOCATIONS ON THE SWEETWATER RIVER, ASSUMING ONE-HALF FULL RESERVOIR CONDITIONS

In cubic feet per second

Location	Routed spills from Sweetwater Reservoir	Flood discharges from area below Sweetwater Reservoir	Total peak discharges
50-year Flood			
At U. S. Highway 101 Bridge	18,600	5,000	23,600
Approx. 800 feet upstream from Intersection of Valley Road and Sweetwater Road	18,600	4,500	23,100
Confluence of Rice Canyon and Sweetwater River	18,750	4,050	22,800
Approx. 700 feet upstream from intersection of Bonita Road and Otay Lakes Road	18,750	3,250	22,000
Approx. 2,100 feet downstream from Sweetwater Dam	18,750	2,250	21,000
100-year Flood			
At U. S. Highway 101 Bridge	34,000	9,250	43,250
Approx. 800 feet upstream from intersection of Valley Road and Sweetwater Road	34,600	7,650	42,250
Confluence of Rice Canyon and Sweetwater River	34,600	6,900	41,500
Approx. 700 feet upstream from intersection of Bonita Road and Otay Lakes Road	34,600	5,400	40,000
Approx. 2,100 feet downstream from Sweetwater Dam	34,600	3,900	38,500

CHAPTER III. AREAS OF POTENTIAL INUNDATION

This chapter describes the final step in the study--determination of the areas of potential inundation along the Sweetwater River from Sweetwater Dam to the river mouth for 50- and 100-year floods. The study was conducted for two different assumed reservoir conditions: (1) both Lake Loveland and Sweetwater Reservoirs initially full, and (2) both Lake Loveland and Sweetwater Reservoirs one-half full initially.

Backwater Curve Computations

By use of Equation 9 in Appendix B, backwater curves were computed for discharges ranging from 55,000 to 8,000 cubic feet per second for the eight-mile-long reach of the Sweetwater River under investigation (between Sweetwater Dam and the river mouth). This range of discharges included the flood peaks presented in Tables 3 and 4. A total of 31 cross sections were selected. The distance between cross sections varied from about 600 feet to about 2,800 feet, with the average distance being about 1,450 feet. The roughness coefficient, n, in the Manning formula varied from 0.026 to 0.055. The energy coefficient, α, varied from 1.0 to 1.3, with the average being about 1.1.

Use of the standard step method of backwater computations requires the establishment of an initial water-surface elevation at the beginning of calculations. The water-surface elevation in San Diego Bay just downstream of Highway 101 Bridge was assumed to be three feet above mean sea level. This assumption was based on the mean of the higher high water above mean sea level for the months of October, November, December, January, February, and March, as published in the 1962 Tide Tables by the

U. S. Coast and Geodetic Survey. Backwater computations were then carried upstream based on a water surface of three feet above mean sea level just downstream of Highway 101 Bridge.

Stage-Discharge Curves

As stated, backwater curves were computed for discharges ranging from 55,000 to 8,000 cubic feet per second for the reaches under consideration. From the results of these backwater curve computations, stage-discharge curves were plotted at selected points along the Sweetwater River. Typical stage-discharge curves for the Sweetwater River near the intersection of Valley Road and Sweetwater Road, and approximately 0.6 mile downstream from Sweetwater Dam, are shown on Figure 15. These curves were then used to determine the stage at selected points for the computed peak discharge shown in Tables 3 and 4.

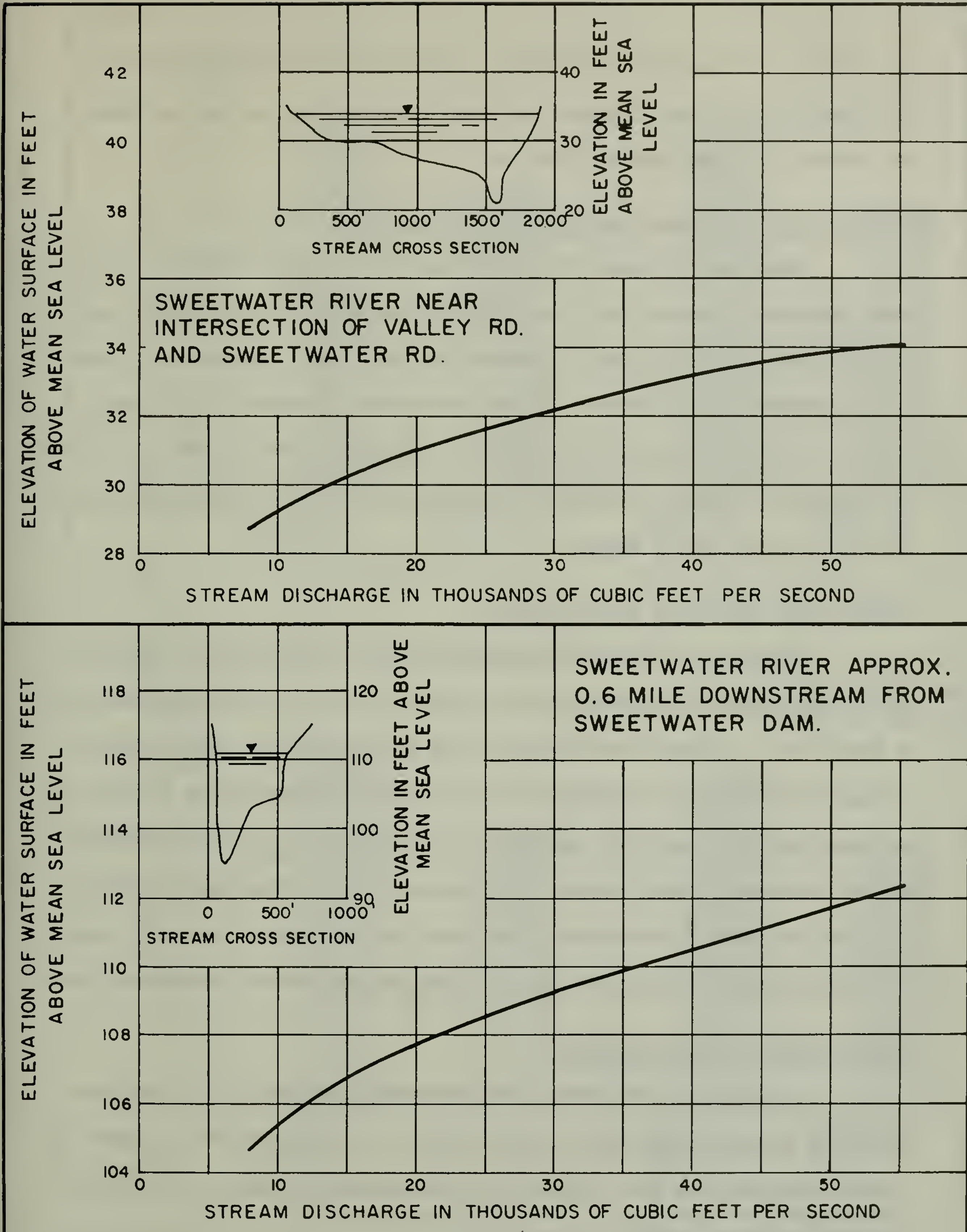
Water-Surface Profiles

From the peak discharges presented in Tables 4 and 5 and the stage-discharge curves for particular points on the stream, the water-surface elevations were determined and the water-surface profiles drawn. A straight line variation in the water-surface profile was assumed between any two successive sections where the stage-discharge relationship was derived. A total of 31 points along the Sweetwater River below Sweetwater Dam were utilized in determining the water-surface profile.

Areas of Potential Inundation

From the water-surface profiles, the elevations of the flood-waters at any point along the river could be ascertained. Areas which would be subject to inundation were then delineated upon topographic maps

FIGURE D-15



TYPICAL STREAM CROSS SECTIONS
AND STAGE DISCHARGE CURVES

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

at a scale of 1 inch equals 200 feet. For purposes of presentation in this report, the areas of potential inundation were delineated on plates at a scale of 1 inch equals 2,000 feet.

Condition of Reservoirs One-Half Full Initially

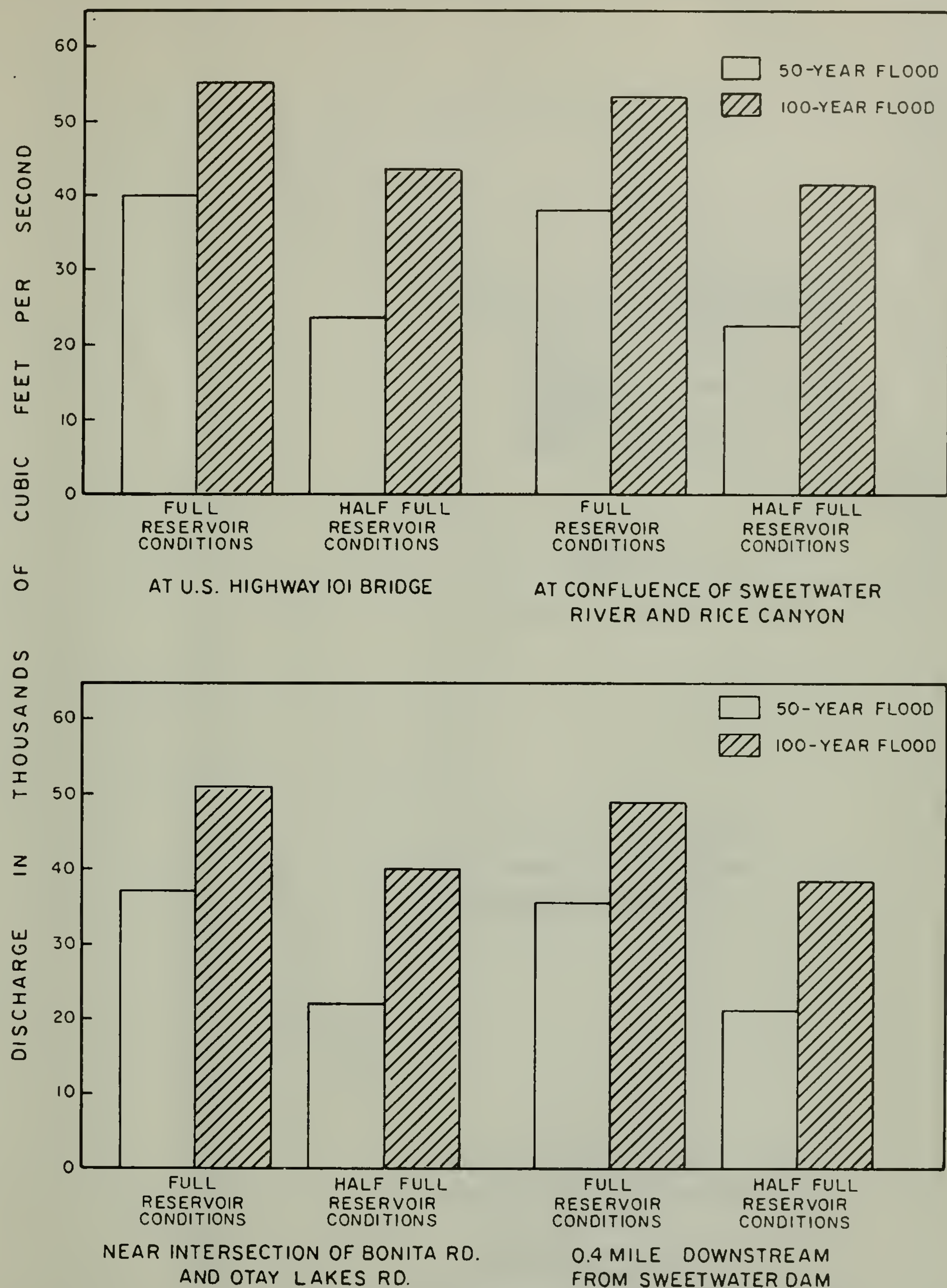
The areas of potential inundation for a flood of 100-year recurrence interval, assuming both Lake Loveland and Sweetwater Reservoirs are one-half full initially, are illustrated on Plate D-2. The area of potential inundation for a flood of 50-year recurrence interval is not shown since the area closely parallels the area delineated for the 100-year flood. The average difference of depth of flow between a 50- and 100-year flood was 1.8 feet for the entire reach.

Condition of Reservoirs Full Initially

The areas of potential inundation for 50- and 100-year floods, assuming Lake Loveland and Sweetwater Reservoirs are full initially, are shown on Plate D-3. Although the 100-year flood is considerably larger than the 50-year flood and the attenuating effect of the full reservoirs is less significant than the reservoirs one-half full initially, the areas inundated by 50- and 100-year floods closely parallel each other. This small difference in depth, an average difference of one foot for the entire reach, is attributed to a large extent to the wide uniform channels of the Sweetwater River.

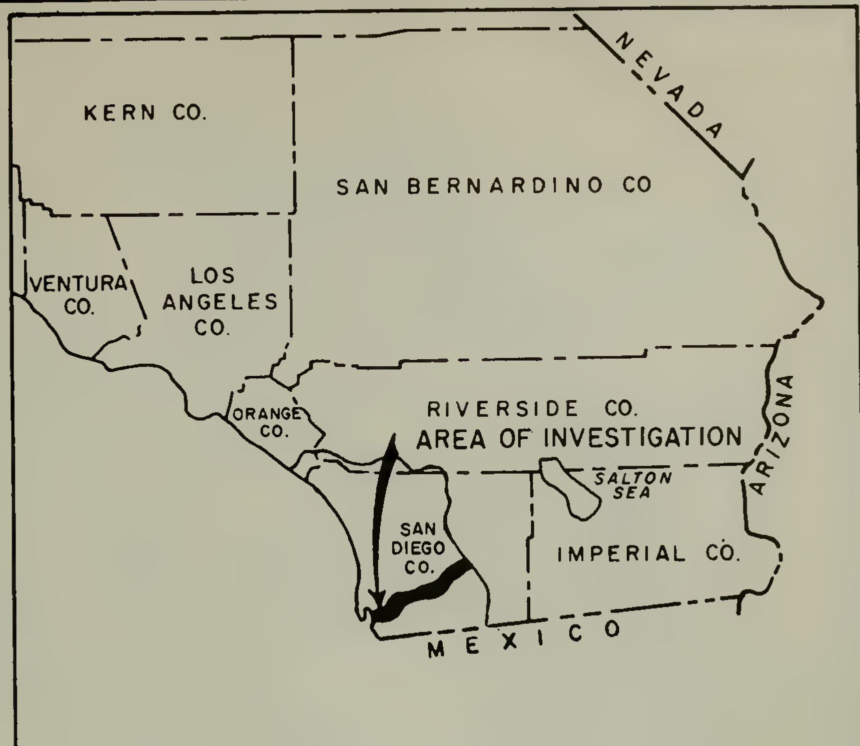
Summary of Peak Flood Discharges

A summary of the peak flood discharges for the 50- and 100-year floods at selected locations along the Sweetwater River for the assumed conditions of reservoirs full initially and reservoirs one-half full initially is shown in Figure D-16.

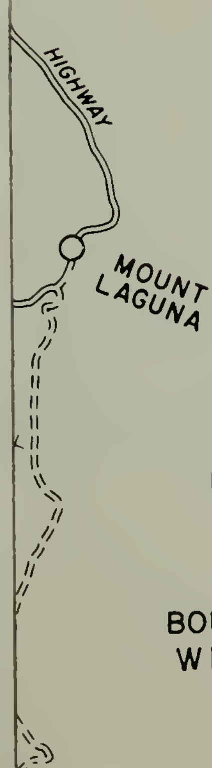


SUMMARY OF PEAK FLOOD DISCHARGES AT SELECTED LOCATIONS ON THE SWEETWATER RIVER

PLATE D-1



LOCATION MAP



LEGEND

— — RIVER BASIN DRAINAGE BOUNDARY

– — — SUBAREA DRAINAGE BOUNDARY

AREA INVESTIGATED FOR POSSIBLE INUNDATION

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

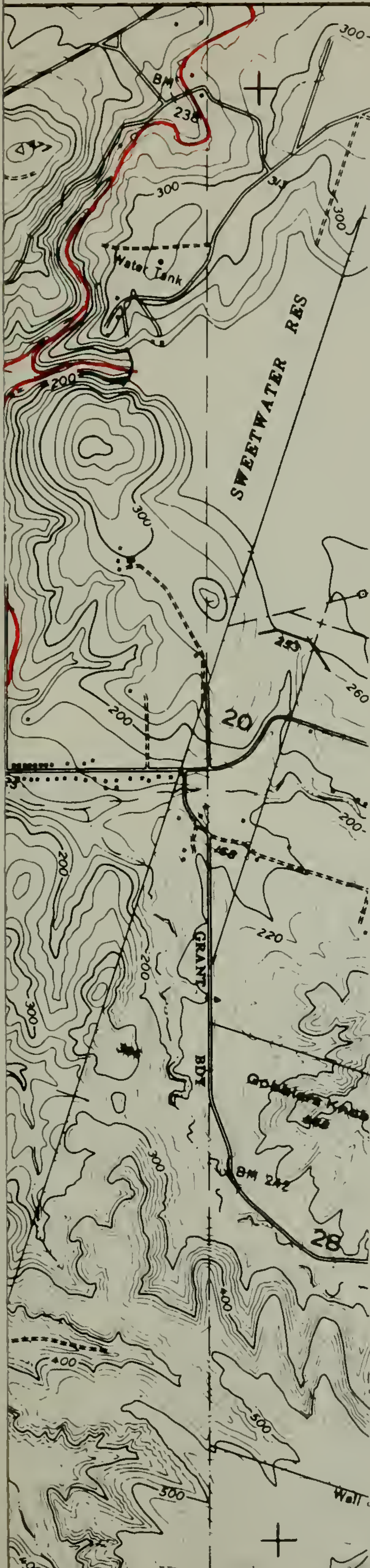
BOUNDARIES OF INVESTIGATIONAL AREA WITHIN SWEETWATER RIVER BASIN

SCALE OF MILES
1 0 1 2 3

1964

PLATE D-1

LOCATION MAP
KERN CO
SAN BERNARDINO CO
NEVADA
VENTURA CO
LOS ANGELES CO
ORANGE CO
RIVERSIDE CO
AREA OF INVESTIGATION
SALTON SEA
SAN DIEGO CO
IMPERIAL CO
ARIZONA
MEXICO
LEGEND
RIVER BASIN DRAINAGE BOUNDARY
SUBAREA DRAINAGE BOUNDARY
AREA INVESTIGATED FOR POSSIBLE INUNDATION
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD
HAZARD INVESTIGATION
BOUNDARIES OF INVESTIGATIONAL AREA
WITHIN SWEETWATER RIVER BASIN
SCALE OF MILES
1 0 1 2 3
1964
MISSION BAY
MISSION BEACH
OCEAN BEACH
POINT LOMA
PACIFIC OCEAN
SAN DIEGO
CORONADO
SAN DIEGO BAY
NATIONAL CITY
CHULA VISTA
IMPERIAL BEACH
PALM CITY
SWEETWATER RESERVOIR
LA MESA
LEMON GROVE
SPRING VALLEY
EL CAJON
SANTEE
LAKESIDE
MURRAY LAKE
CHOLLAS RESERVOIR
EL CAPITAN RESERVOIR
ALPINE
LOVELAND RESERVOIR
SWEETWATER RIVER
JAMUL
UPPER OTAY RESERVOIR
LOWER OTAY RESERVOIR
BARRETT LAKE
DESCANSO
CUYAMACA PEAK
CUYAMACA RESERVOIR
PINE VALLEY
CORTE MADERA LAKE
MOUNT LAGUNA



LEGEND

INUNDATED AREA FOR 50 AND 100 YEAR FLOODS

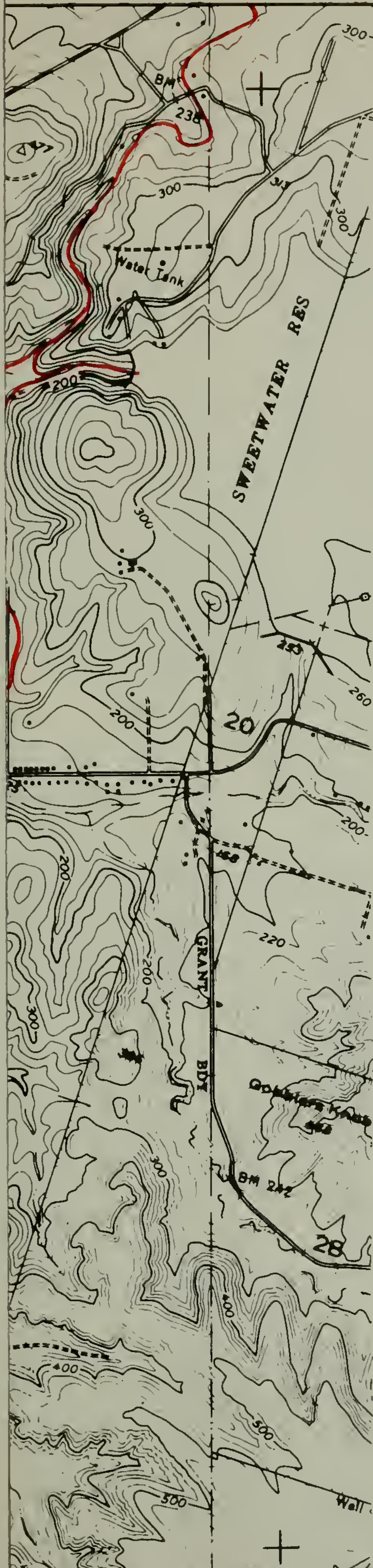
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SWEETWATER RIVER AREAS OF POTENTIAL INUNDATION WHEN RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET

1000 0 1000 2000

1964



LEGEND

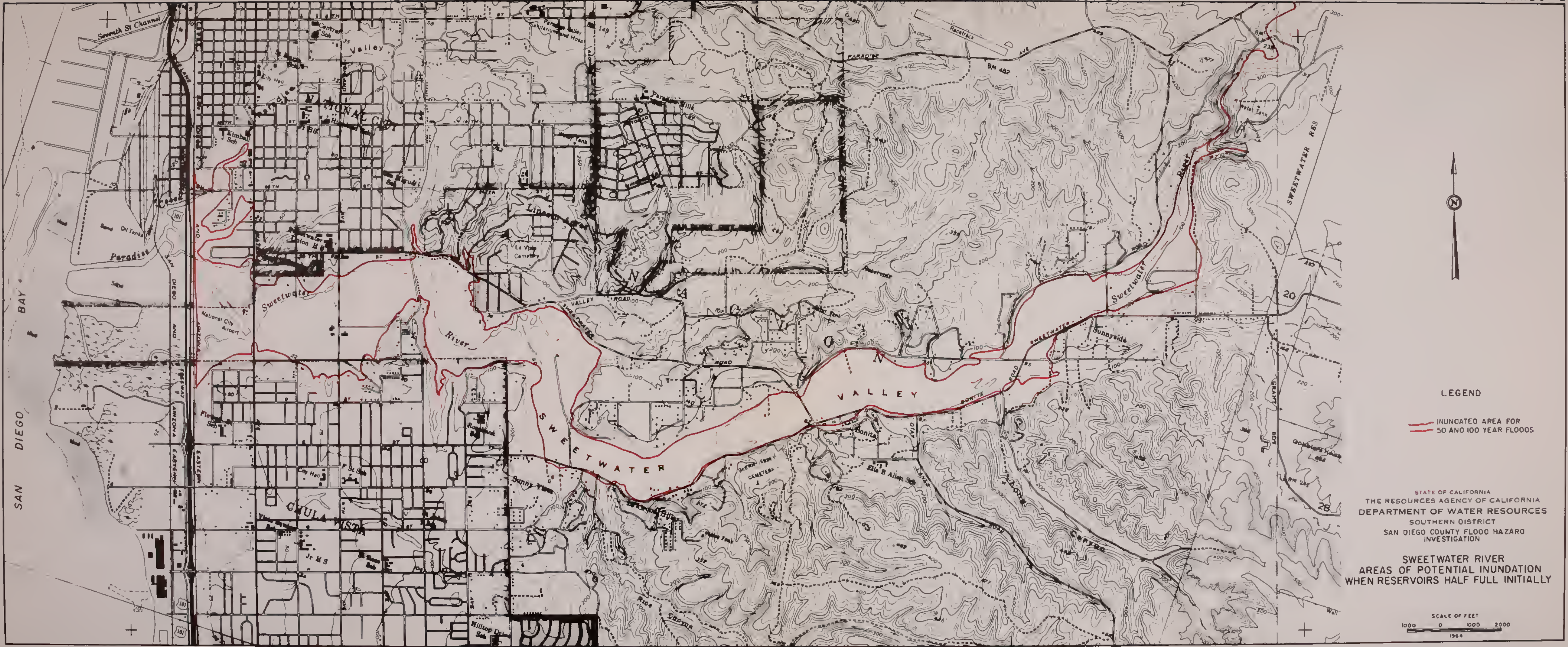
INUNDATED AREA FOR
50 AND 100 YEAR FLOODS

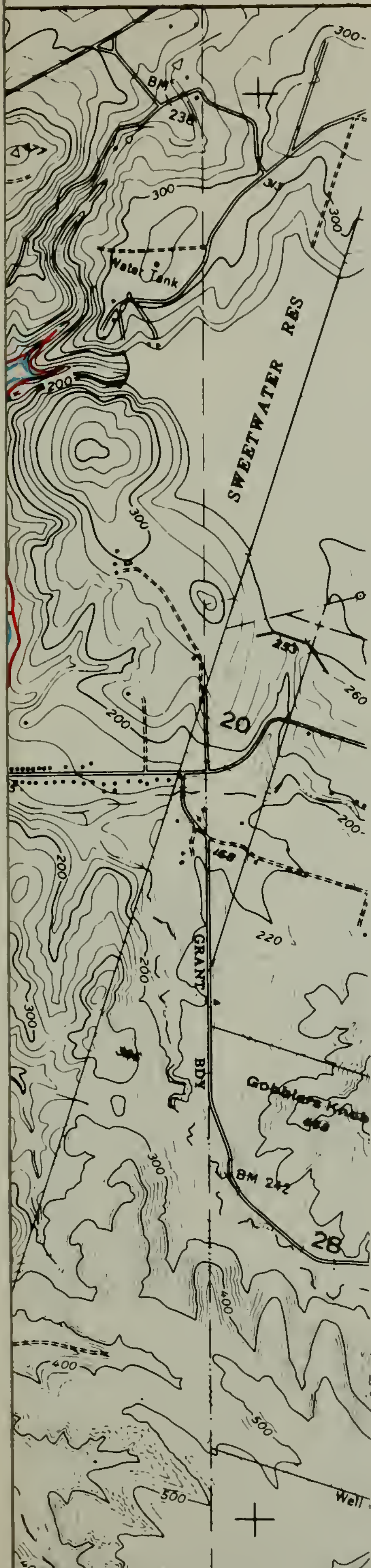
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SWEETWATER RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000

1964


SAN DIEGO BAY
NATIONAL CITY
CHULA VISTA
SWEETWATER
VALLEY
Sweetwater River
Bonita
Sunnyside
National City Airport
LEGEND
INUNDATED AREA FOR
50 AND 100 YEAR FLOODS
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION
SWEETWATER RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS HALF FULL INITIALLY
SCALE OF FEET
1000 0 1000 2000
1964



LEGEND

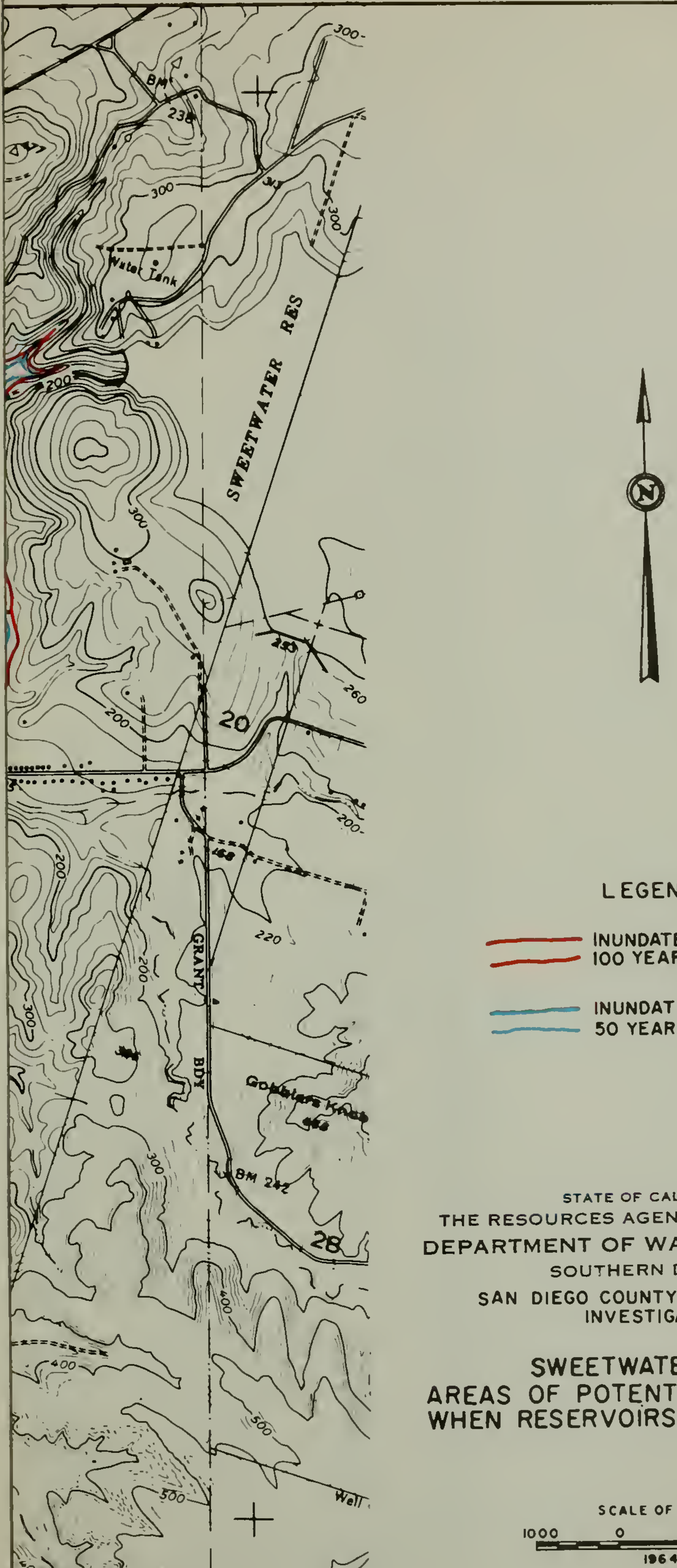
INUNDATED AREA FOR 100 YEAR FLOOD

INUNDATED AREA FOR 50 YEAR FLOOD

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SWEETWATER RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964



LEGEND

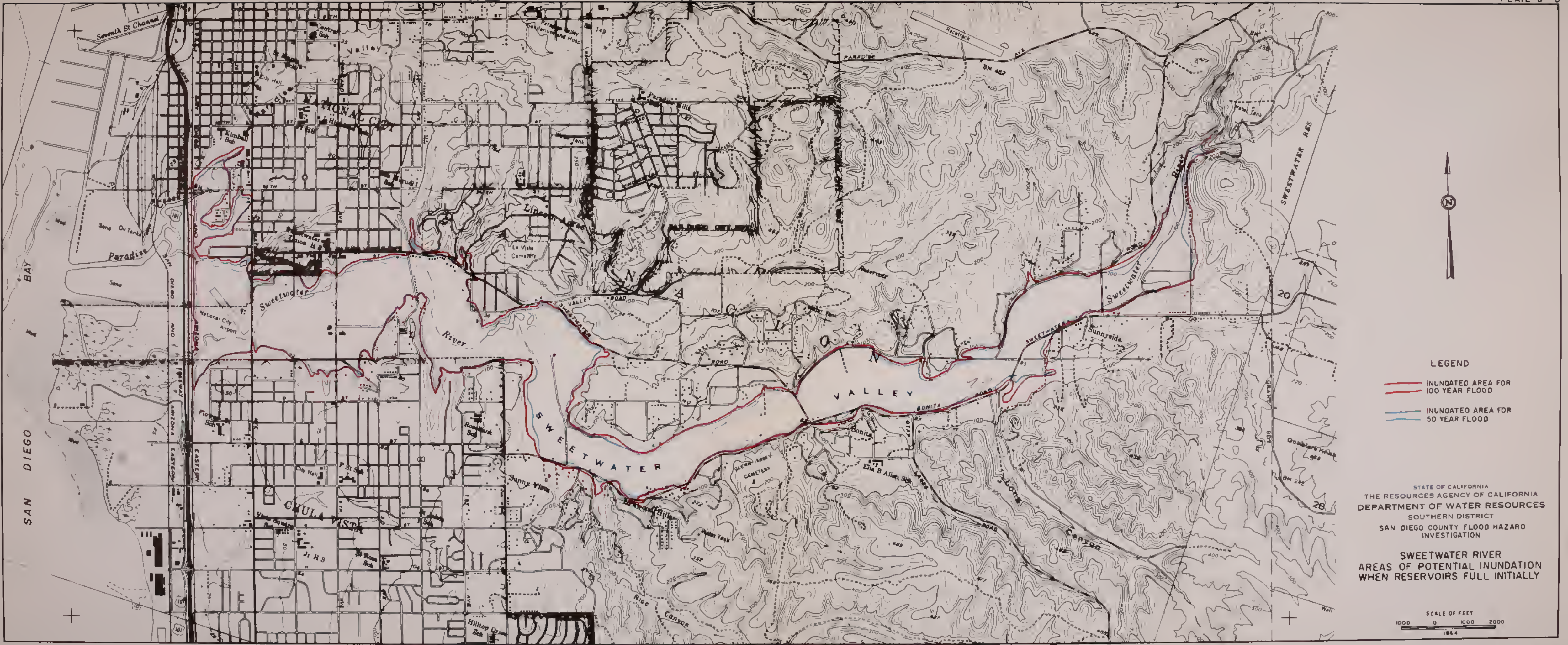
INUNDATED AREA FOR 100 YEAR FLOOD

INUNDATED AREA FOR 50 YEAR FLOOD

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SWEETWATER RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964


LEGEND
INUNDATED AREA FOR 100 YEAR FLOOD
INUNDATED AREA FOR 50 YEAR FLOOD
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION
SWEETWATER RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS FULL INITIALLY
SCALE OF FEET
1000 0 1000 2000
SAN DIEGO BAY
NATIONAL CITY
CHULA VISTA
SWEETWATER VALLEY
SWEETWATER RES
Sweetwater River
Seventh St Channel
Paradise
National City Airport
La Vista Cemetery
Sunnyside
Bonita
Ella B Allen Sch
Sunny Vista
Rice Canyon
Bonita Road
Paradise Valley
Hilltop Drive Sch

APPENDIX E

OTAY RIVER - AREAS OF POTENTIAL INUNDATION

APPENDIX E

OTAY RIVER - AREAS OF POTENTIAL INUNDATION

APPENDIX E

OTAY RIVER - AREAS OF POTENTIAL INUNDATION

TABLE OF CONTENTS

TABLES

FIGURES

PLATES
(Plates follow text of Appendix)

CHAPTER I. INTRODUCTION

Magnitudes of peak flood flows at selected stations along the Otay River between Savage Dam (Lower Otay Dam) and the river mouth for flood peaks having a 50- and 100-year recurrence interval are discussed in this appendix. Maps illustrating areas inundated by these floods are presented at the end of the appendix.

The methodology utilized in this appendix for reservoir and stream channel flood routing and for backwater computations follows commonly used techniques as described in detail in Appendix B. Water-surface profiles thus determined were plotted on maps to indicate the areas of potential inundation.

Scope of Investigation

The studies of the flood potential of the Otay River were directed toward producing reliable estimates of water-surface profiles for flood peaks of 50- and 100-year recurrence intervals, and to delineate the areas which might be inundated by these floods. The work necessary to accomplish these objectives consisted of establishing reliable estimates of peak flood flows, determining hydraulic properties of the flood channels at selected intervals, calculating water-surface profiles along the approximately 12 miles of floodplain from Savage Dam to the Otay River mouth, and delineating areas of potential inundation.

Description of Area of Investigation

The Otay River watershed has an area of 148 square miles and lies on the western slopes of the Coast Range, partially separating the watersheds of the Tia Juana and Sweetwater Rivers. The river flows generally southwesterly and discharges into the Pacific Ocean through San Diego Bay. Its length is approximately 24 miles, half of which lies in the higher elevations above Lower Otay Reservoir.

The upper portion of the Otay River Basin becomes more rugged at higher elevations, but the lower portion of the basin consists of high mesa lands and valleys. Elevations throughout the basin range from sea level to about 500 feet in the lower portion and from about 500 to 3,250 feet in the mountains. The mean annual precipitation varies from approximately 11 inches in the lower portion to approximately 20 inches in the mountains. The extremes of discharge into Lower Otay Reservoir have varied from no discharge to 37,400 cubic feet per second at the time of the January 1916 flood.

There are two major reservoirs, Upper Otay and Lower Otay Reservoirs, within the Otay River watershed. Upper Otay Reservoir on Proctor Valley Creek, a tributary of the Otay River, with a capacity of 2,825 acre-feet is used to store local water for municipal purposes. Lower Otay Reservoir on the Otay River, with a capacity of 56,326 acre-feet, is used to store local water and water imported from the Colorado River through the Second San Diego Aqueduct. Both reservoirs are owned and operated by the City of San Diego for municipal purposes.

The reach of the Otay River Basin considered for potential flood hazards is that portion from Savage Dam to the river mouth. The communities of Otay and Palm City and the City of Imperial Beach lie within the study area. The Otay River Basin and the area of investigation are delineated on Plate E-1, "Boundaries of Investigational Area and Tributary Drainage Basin for Otay River."

CHAPTER II. PEAK FLOOD FLOWS

Determination of peak flood flows at the 50- and 100-year frequency level for ungaged reaches of the Otay River and its tributaries is presented in this chapter. The method outlined herein combined the use of regression equations and techniques of reservoir and river channel flood routing. The development of the equations was discussed in detail in Appendix A, "Regional Flood Frequency Analysis," and the routing techniques utilized are explained in Appendix B, "Methods and Procedures."

Determination of Flood Discharges from Ungaged Areas

The estimated peak discharges at selected ungaged points on the Otay River, as a result of runoff emanating from areas below Savage Dam for floods of 50- and 100-year recurrence intervals, are presented in Table 1. These values of discharge were determined by use of Figures B-1 and B-2 in Appendix B.

The estimated unimpaired peak flood discharges from areas above Lower and Upper Otay Reservoirs were determined in the same manner as for the areas below the reservoirs. The estimated 50- and 100-year flood peaks for the 86-square-mile drainage area above Lower Otay Reservoir were found to be 16,400 and 22,200 cubic feet per second, respectively. The estimated 50- and 100-year flood peaks for the 13-square-mile drainage area above Upper Otay Reservoir were found to be 5,200 and 7,000 cubic feet per second, respectively.

The shape of the flood hydrograph characterized by these peaks is shown on Figure B-3 and is discussed further in Appendix B.

TABLE 1

ESTIMATED PEAK FLOOD DISCHARGES FROM AREAS BELOW LOWER OTAY RESERVOIR FOR SELECTED LOCATIONS ON THE OTAY RIVER

Location	Drainage area, in square miles[a]	Diameter of circle of equivalent area, in miles	Basin length, in miles	Shape factor Sh	Peak discharge, in cubic feet per second	
					50-year flood	100-year flood
At San Diego and Eastern R.R. Bridge	46.9	7.7	11.0	0.70	11,500	15,500
Confluence of Poggi Canyon and Otay River	36.4	6.7	8.3	0.82	9,200	12,300
Stream mile 6.5 from mouth	30.2	6.2	7.2	0.87	8,050	10,700
Confluence of Wolf Canyon and Otay River	26.5	5.8	5.4	1.10	6,800	8,700
Approx. 1,500 feet downstream from confluence of Johnson Canyon and Otay River	20.0	5.0	3.3	1.60	4,900	6,000

a. Excludes 99 square miles of drainage area above Lower Otay Reservoir

These flood peaks obtained from Figures B-1 and B-2 in Appendix B are attenuated by storage capacity available in the reservoirs, as well as channel storage, and the resulting diminished outflow was combined with the values shown in Table 1 to determine the total discharge at various points.

Effect of Reservoir and Channel Storage on Peak Flood Flows

This section shows the attenuating effect of reservoir and channel storage on peak flood flows. The reduction of flood peaks as a result of flood flows entering reservoir storage will be discussed first, followed by a description of the effect of channels on flood peaks.

Reservoir Flood Routing

The derived 50- and 100-year flood hydrographs were routed through Upper and Lower Otay Reservoirs. Two initial reservoir conditions were assumed: (1) Upper and Lower Otay Reservoirs one-half full; and (2) both reservoirs full.

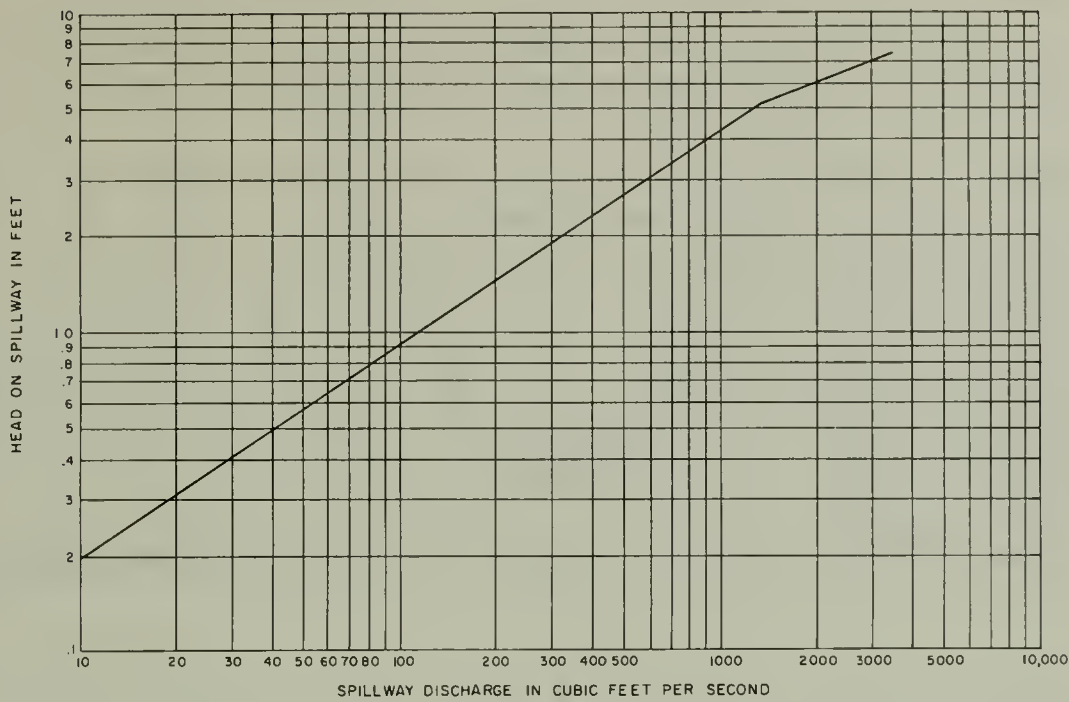
Upper Otay Reservoir. Utilizing the storage capacity curve and the spillway discharge curve for Upper Otay Reservoir as shown on Figure E-1, flood flows for the 50- and 100-year recurrence intervals were routed through the reservoir. As stated, this was done assuming two initial conditions at Upper Otay Reservoir: one-half full (1,412 acre-feet) and full (2,825 acre-feet).

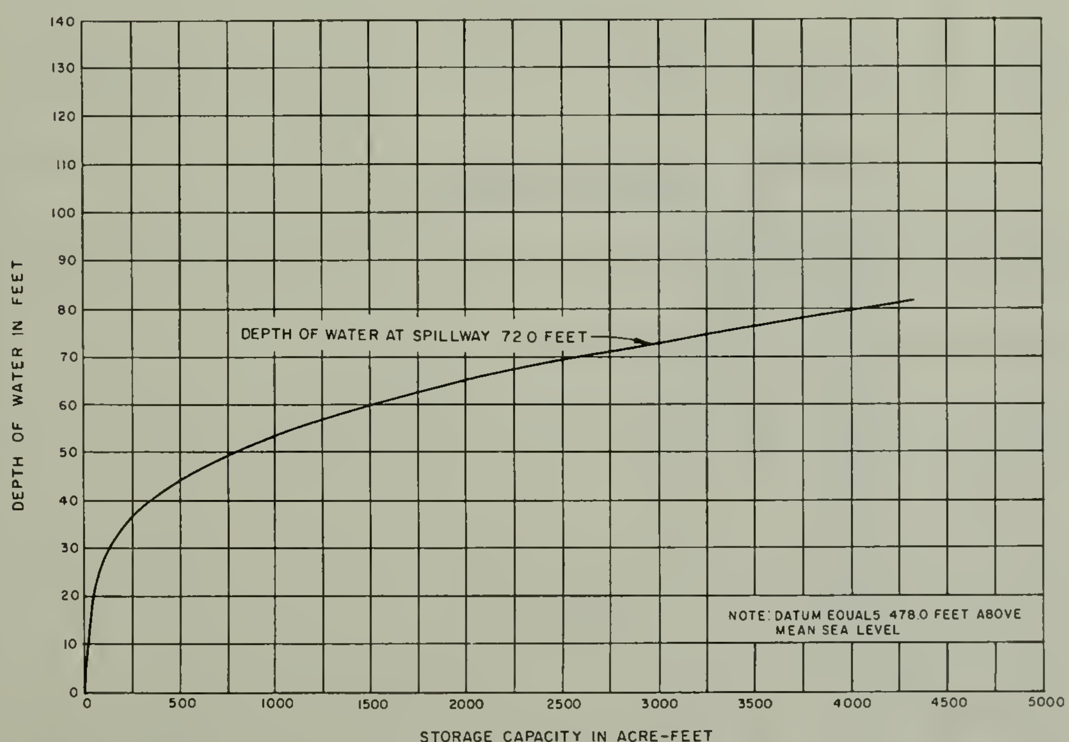
With the reservoir full initially, the flood peaks for the inflow and outflow hydrographs at the 100-year recurrence interval are 7,000 and 6,600 cubic feet per second, respectively, with a lag of about one hour between the peaks. At the 50-year flood recurrence interval the flood peaks are approximately 5,200 and 4,750 cubic feet per second for the inflow and outflow hydrographs, respectively, with a lag of about two hours between the peaks. The inflow and outflow hydrographs for these conditions are illustrated on Figure E-2.

When the reservoir is assumed to be one-half full initially, the flood peaks for the inflow and outflow hydrographs at the 100-year recurrence interval are 7,000 and 6,400 cubic feet per second, respectively, with a lag of about two hours between the peaks. At the 50-year flood recurrence interval the flood peaks are approximately 5,200 and 4,300 cubic feet per second for the inflow and outflow hydrographs, respectively, with a lag of about four hours between the peaks. These hydrographs are depicted on Figure E-3.

Lower Otay Reservoir. Utilizing the storage capacity curve and the spillway discharge curve for Lower Otay Reservoir as shown on Figure E-4, flood flows for the 50- and 100-year recurrence intervals were routed through the reservoir. The flood flows into Lower Otay Reservoir are the combined flows for the tributary areas between Lower and Upper Otay Reservoirs and the routed outflows from Upper Otay Reservoir. As stated, this was done assuming two initial reservoir conditions at Lower Otay Reservoir: one-half full (28,163 acre-feet) and full (56,326 acre-feet).

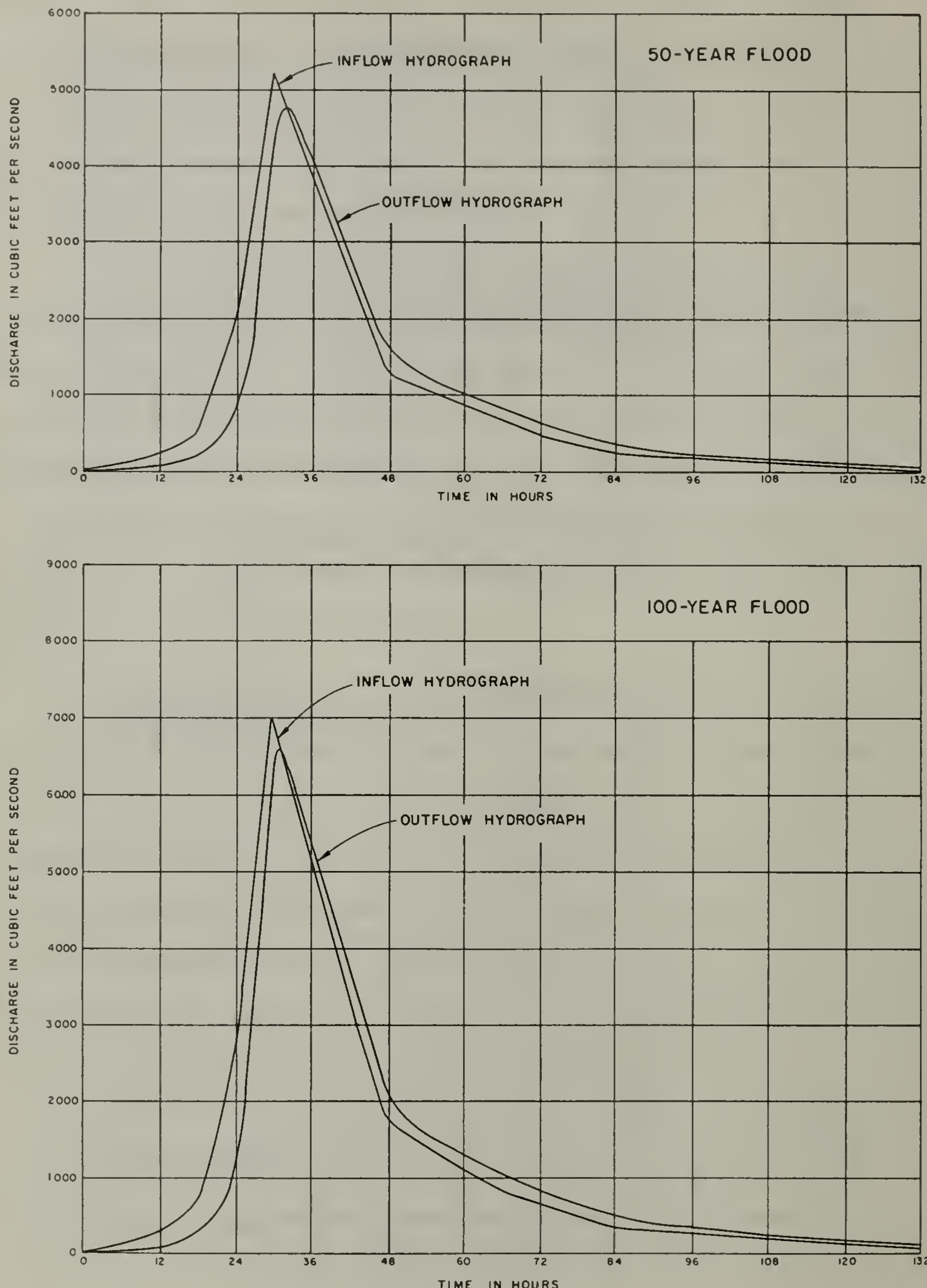
With the reservoir full initially, the flood peaks for the inflow and outflow hydrographs at the 100-year recurrence interval are 28,400 and 23,250 cubic feet per second, respectively, with a lag of about four hours between the peaks. At the 50-year flood recurrence interval the flood





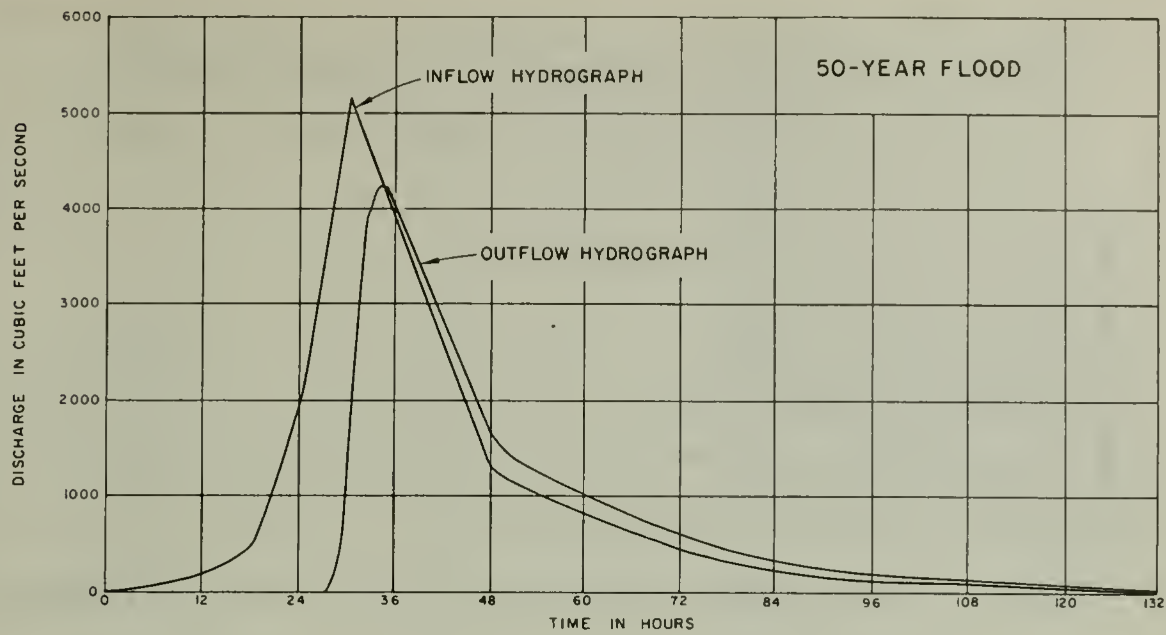
SPILLWAY DISCHARGE AND STORAGE CAPACITY CURVES FOR UPPER OTAY RESERVOIR

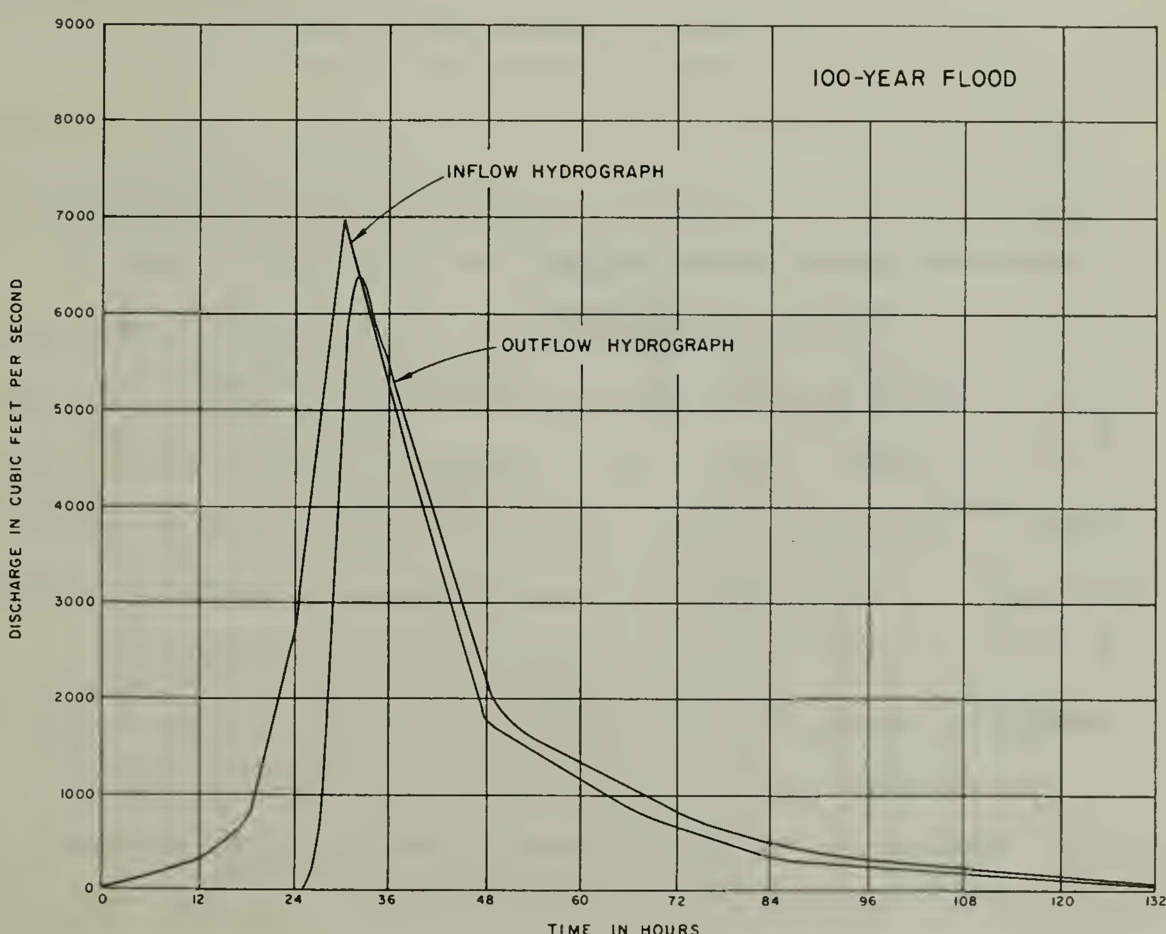
FIGURE E-2



INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT UPPER OTAY RESERVOIR
ASSUMING FULL RESERVOIR CONDITIONS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

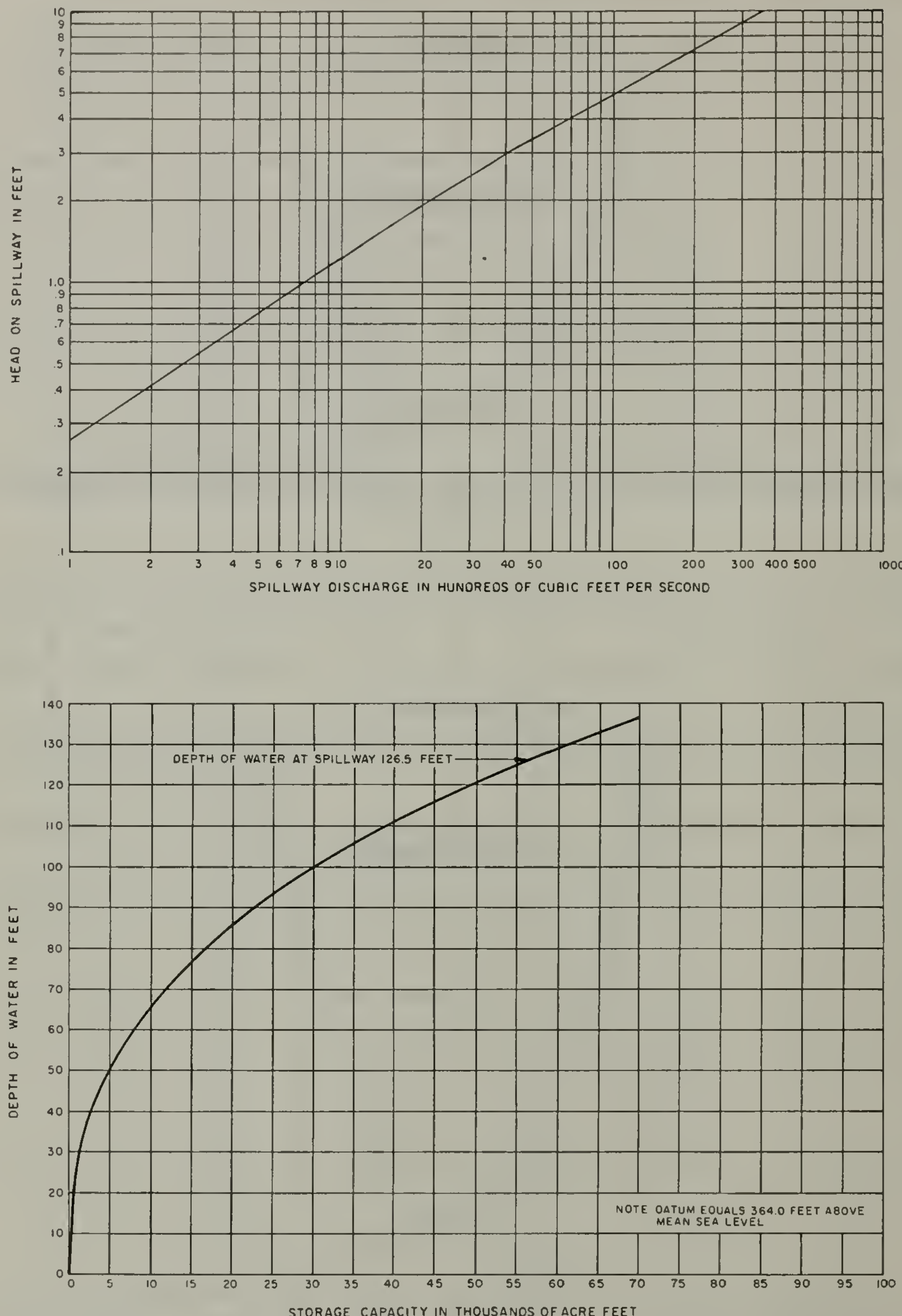




INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT UPPER OTAY RESERVOIR
ASSUMING HALF-FULL RESERVOIR CONDITIONS

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

FIGURE E-4



SPILLWAY DISCHARGE AND STORAGE CAPACITY
CURVES FOR LOWER OTAY RESERVOIR

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964

peaks are approximately 20,700 and 16,600 cubic feet per second for the inflow and outflow hydrographs, respectively, with a lag of about five hours between the peaks. Results of routing with the reservoir full initially are presented on Figure E-5.

When the reservoir is assumed to be one-half full initially, the peak outflow at the 100-year recurrence interval was 9,400 cubic feet per second, with a lag of about 17 hours between hydrograph peaks. For a 50-year flood, the peak outflow was only 3,000 cubic feet per second, with a lag of about 35 hours between hydrograph peaks. The inflow and outflow hydrographs for these conditions are shown on Figure E-6.

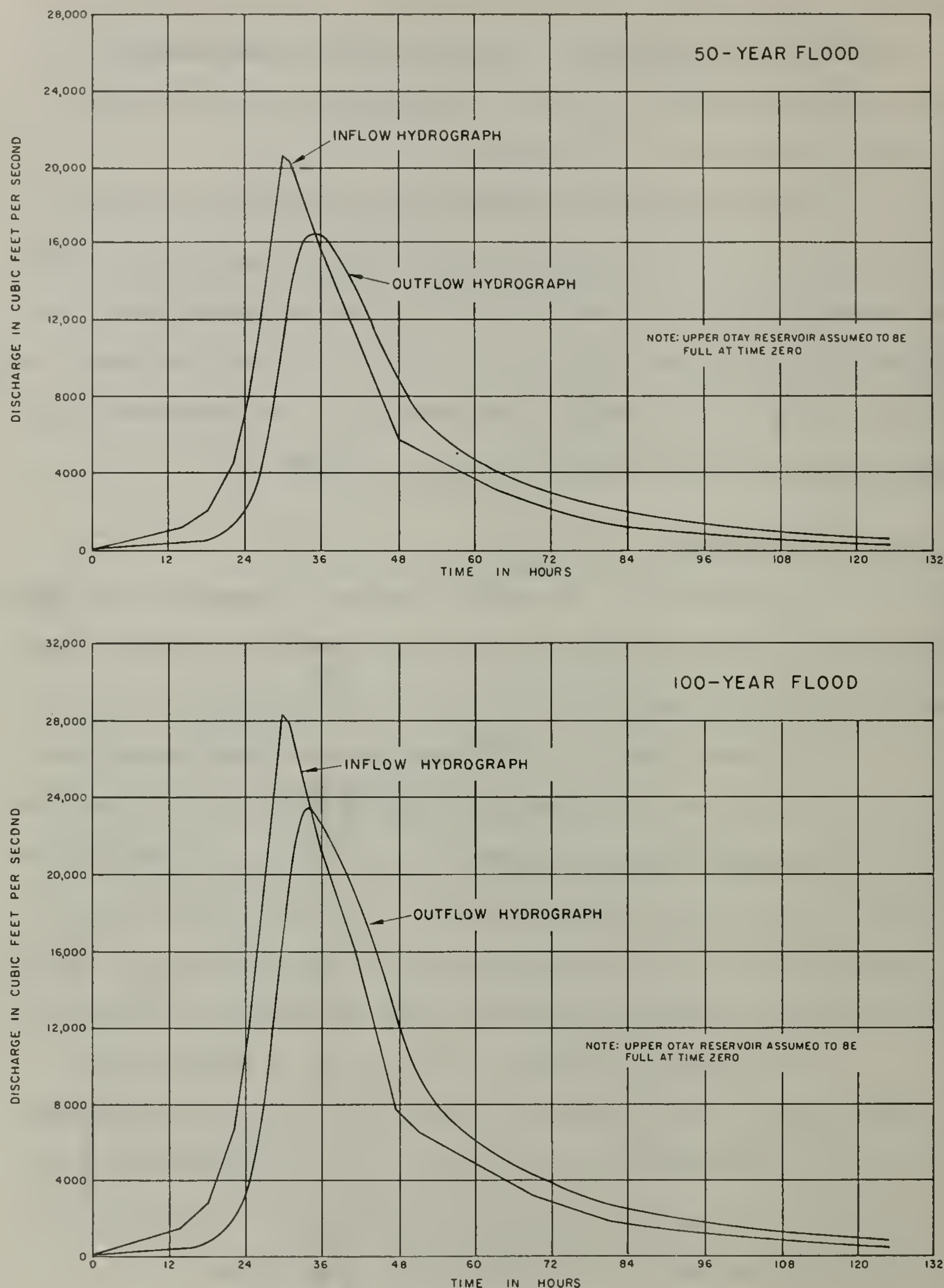
Stream Flood Routing

By utilization of the method described in Appendix B, the hydrographs from Lower Otay Reservoir were routed downstream to develop hydrographs at the river mouth.

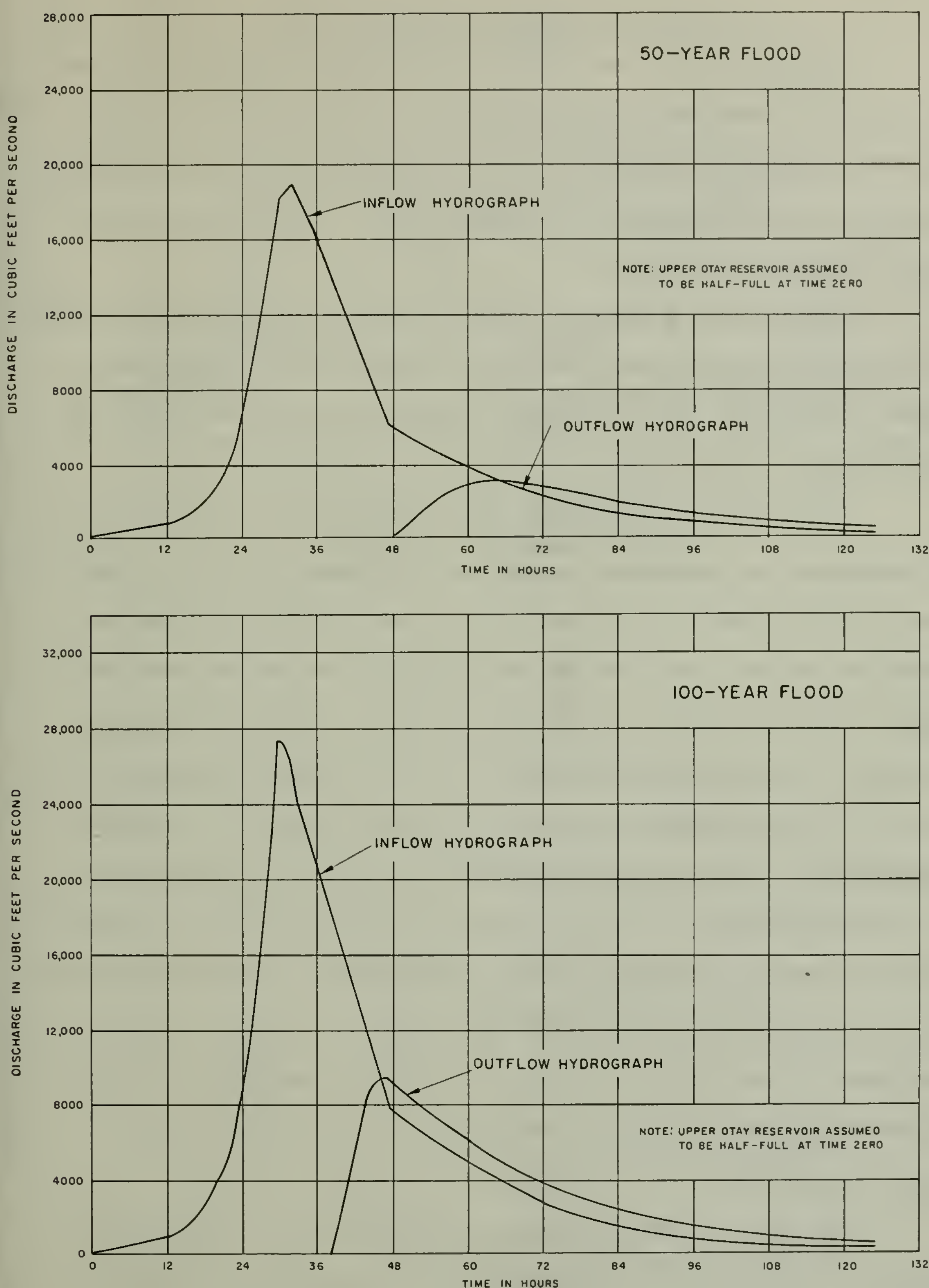
The travel time, T, for the reach between Savage Dam and the mouth of the river was determined by estimating the velocity of the flood wave. The velocity of the flood wave for the reach was assumed to be the average of the velocities determined in the backwater computations for discharges of 35,000, 25,000 and 15,000 cubic feet per second. A velocity of 7.6 feet per second was used with a resulting value of 2.3 hours for T.

By utilizing the value of T of 2.3 hours in Equation (7) of Appendix B and a routing period, t, of one hour, the outflow hydrographs were generated at the mouth of the river. Due to the similarity of the hydrographs at Savage Dam and the mouth of the river, it was possible to derive the hydrographs at river mile 6.5 by interpolation.

FIGURE E-5



INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT LOWER OTAY RESERVOIR
ASSUMING FULL RESERVOIR CONDITIONS



INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT LOWER OTAY RESERVOIR
ASSUMING HALF-FULL RESERVOIR CONDITIONS

Determination of Total Peak Flood Flows

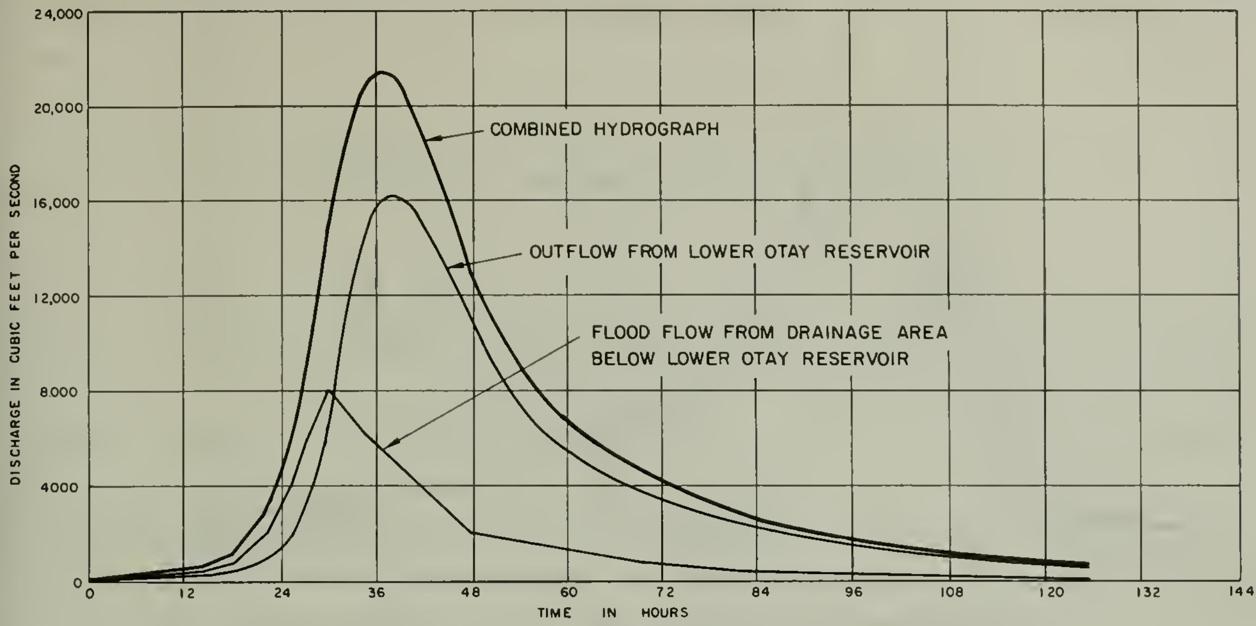
The peak flood flows at each selected point along the reach of the Otay River under study, namely, that portion downstream from Savage Dam, were determined by combining flood hydrographs of the routed overflows from Lower Otay Reservoir with the hydrographs of flows from the contributing area below the reservoir.

The combined hydrographs at stream mile 6.5 on the Otay River for 50- and 100-year floods, with reservoirs initially full, are depicted on Figures E-7 and E-8. The hydrographs at the mouth of the Otay River are shown on Figures E-9 and E-10.

For the initial condition where the reservoirs are one-half full, the spill from the reservoirs, except for the 100-year flood at stream mile 6.5, did not add to the peak because of the considerable time lag between the earlier peak flow from the tributary areas below Lower Otay Reservoir and the subsequent peak reservoir spill. The peak discharge, therefore, was the discharge determined for the tributary area below the reservoir, which corresponds to the values shown in Table 1. The peak discharge for a 100-year flood at stream mile 6.5 was the discharge from the combined hydrograph. The flood hydrographs at stream mile 6.5 on the Otay River for 50- and 100-year floods, respectively, with reservoirs one-half full initially, are illustrated on Figures E-11 and E-12. The flood hydrographs for the mouth of the Otay River for 50- and 100-year floods, respectively, with reservoirs one-half full initially, are shown on Figures E-13 and E-14.

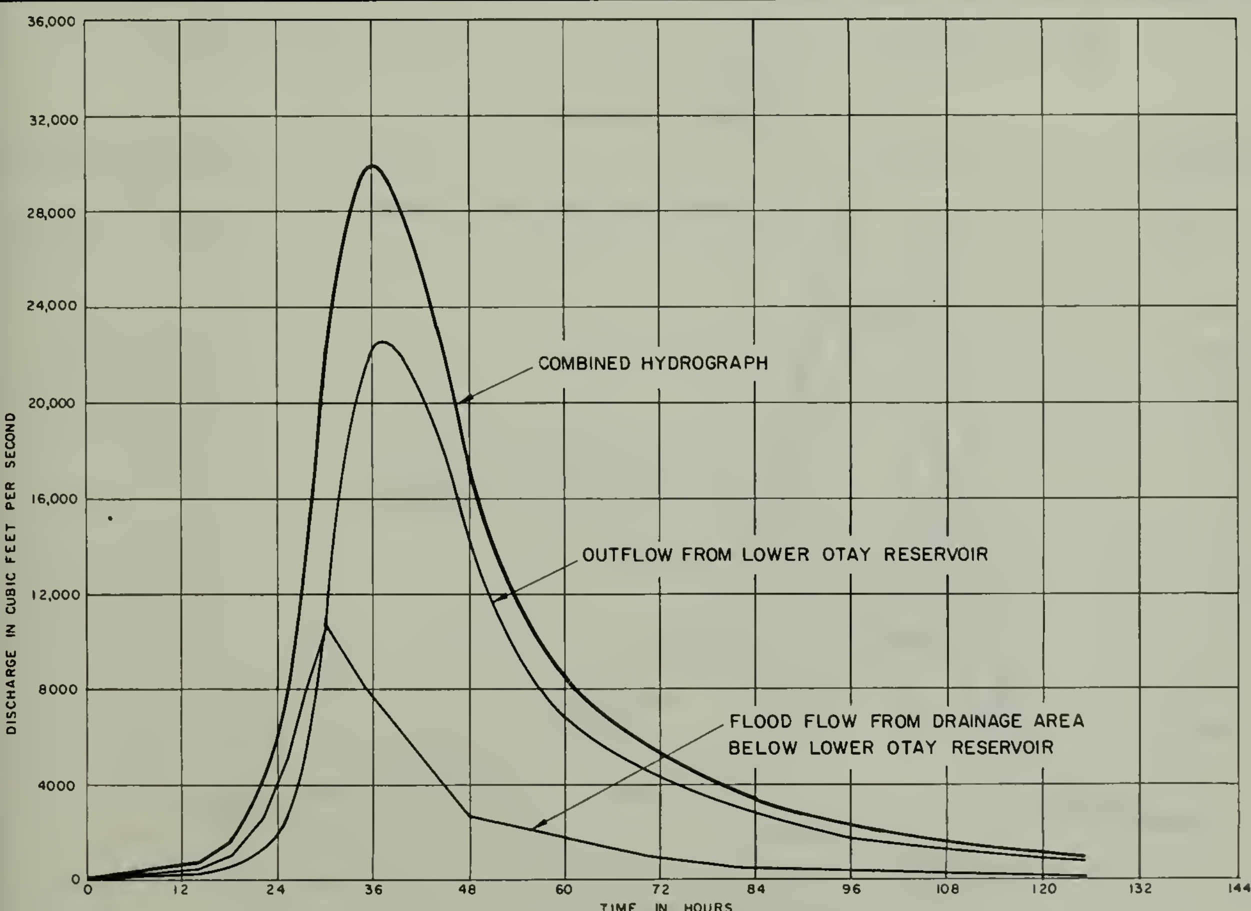
In Table 2, peak discharges are summarized for 50- and 100-year floods at selected points along the Otay River downstream from Savage Dam

FIGURE E-7



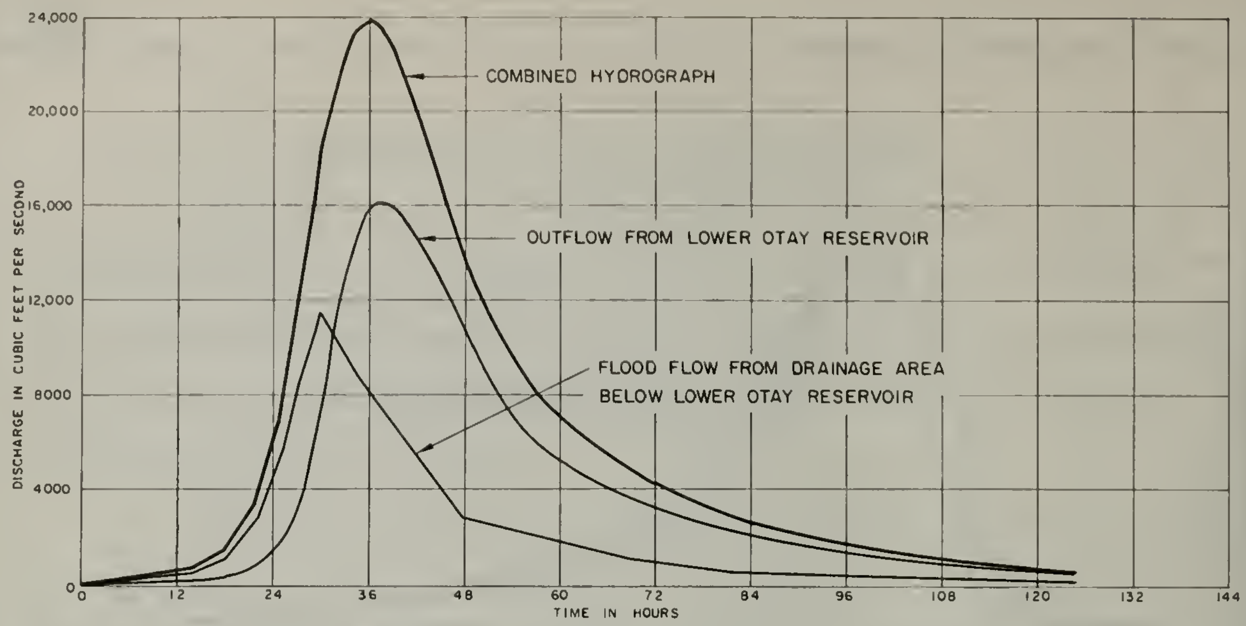
FLOOD HYDROGRAPH AT STREAM MILE 6.5 OF OTAY RIVER
FOR 50-YEAR FLOOD
ASSUMING FULL RESERVOIR CONDITIONS

FIGURE E-8



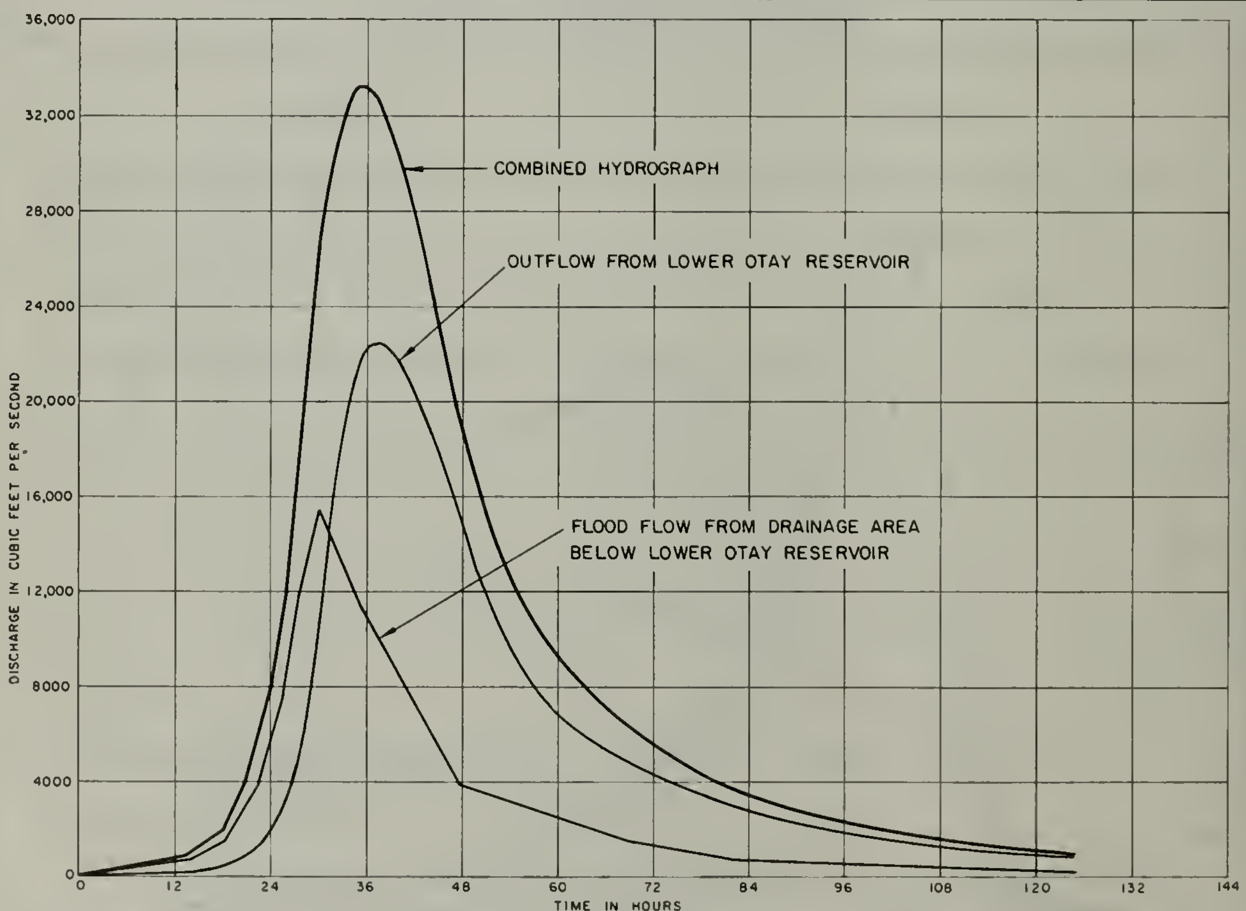
FLOOD HYDROGRAPH AT STREAM MILE 6.5 OF OTAY RIVER
FOR 100-YEAR FLOOD
ASSUMING FULL RESERVOIR CONDITIONS

FIGURE E-9

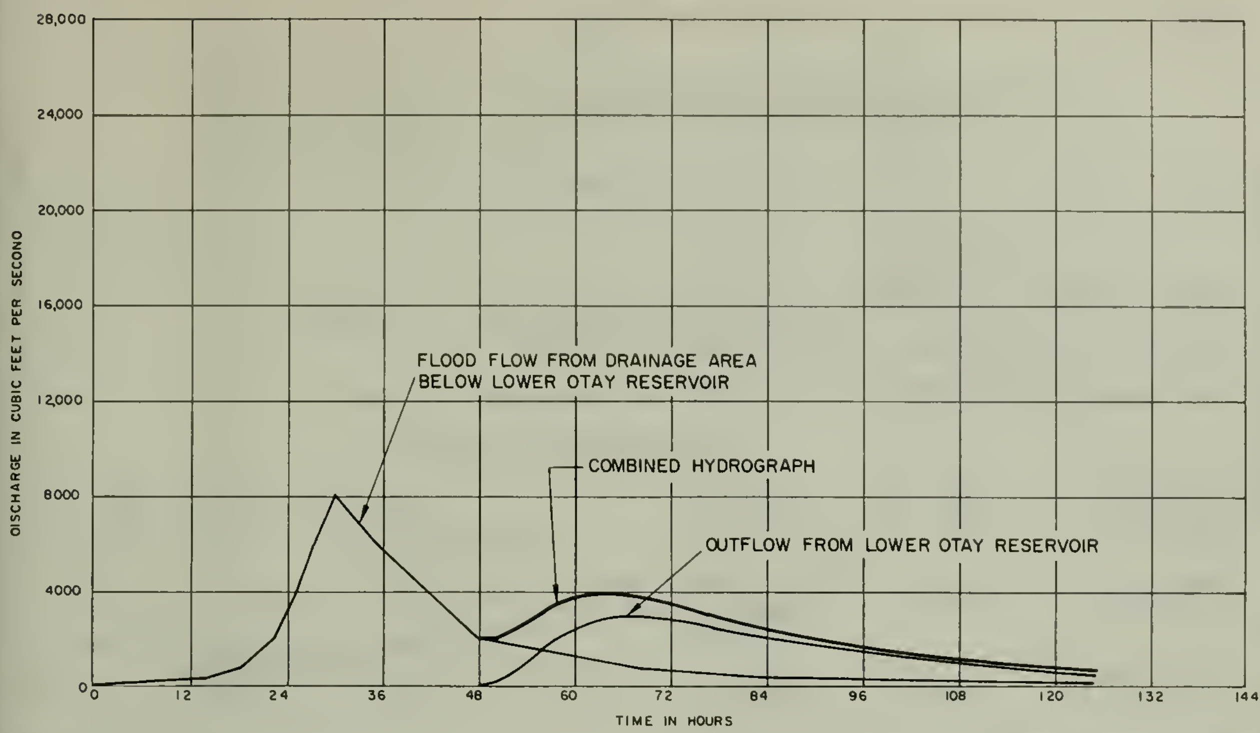


FLOOD HYDROGRAPH AT MOUTH OF OTAY RIVER
FOR 50-YEAR FLOOD
ASSUMING FULL RESERVOIR CONDITIONS

FIGURE E-10

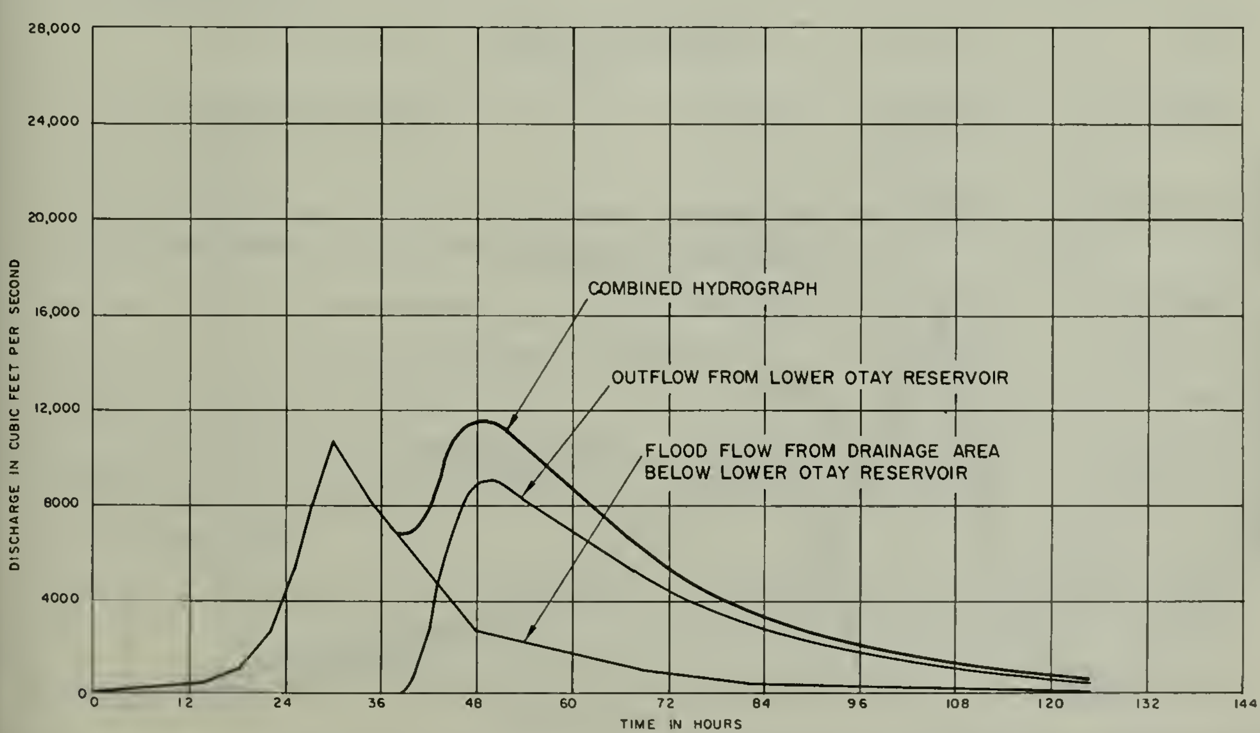


FLOOD HYDROGRAPH AT MOUTH OF OTAY RIVER
FOR 100-YEAR FLOOD
ASSUMING FULL RESERVOIR CONDITIONS



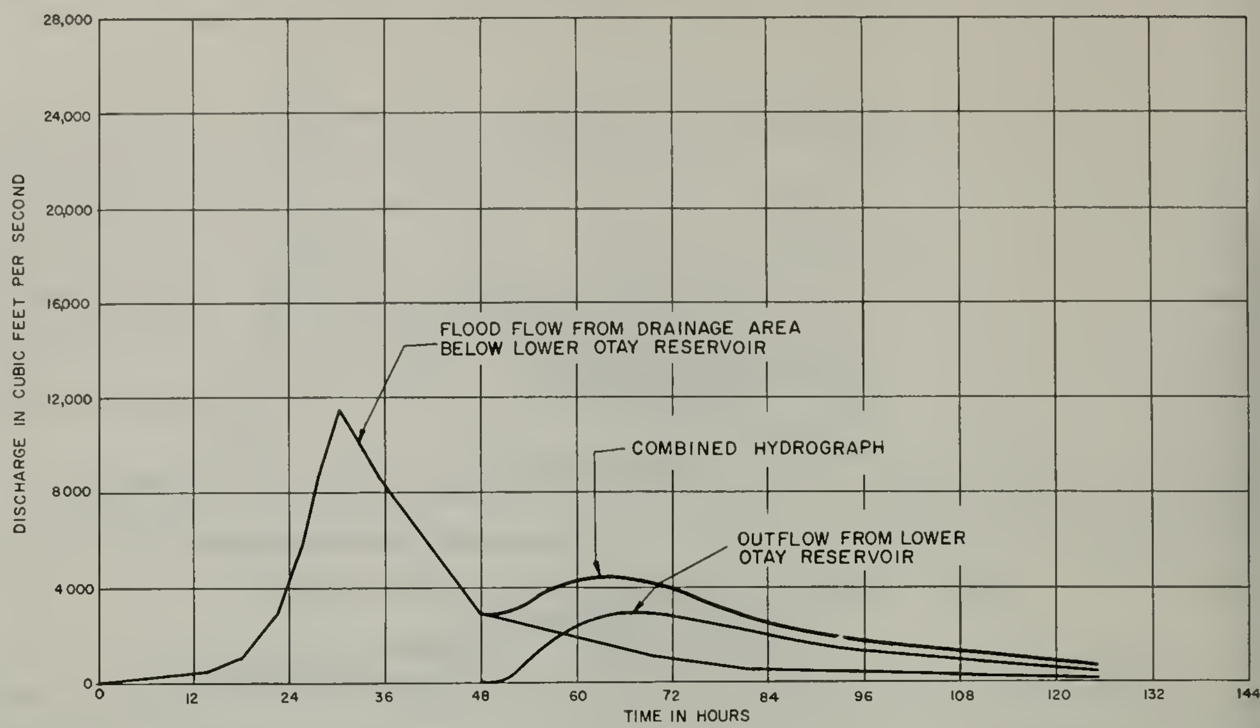
FLOOD HYDROGRAPH AT STREAM MILE 6.5 OF OTAY RIVER
FOR 50-YEAR FLOOD
ASSUMING HALF-FULL RESERVOIR CONDITIONS

FIGURE E-12



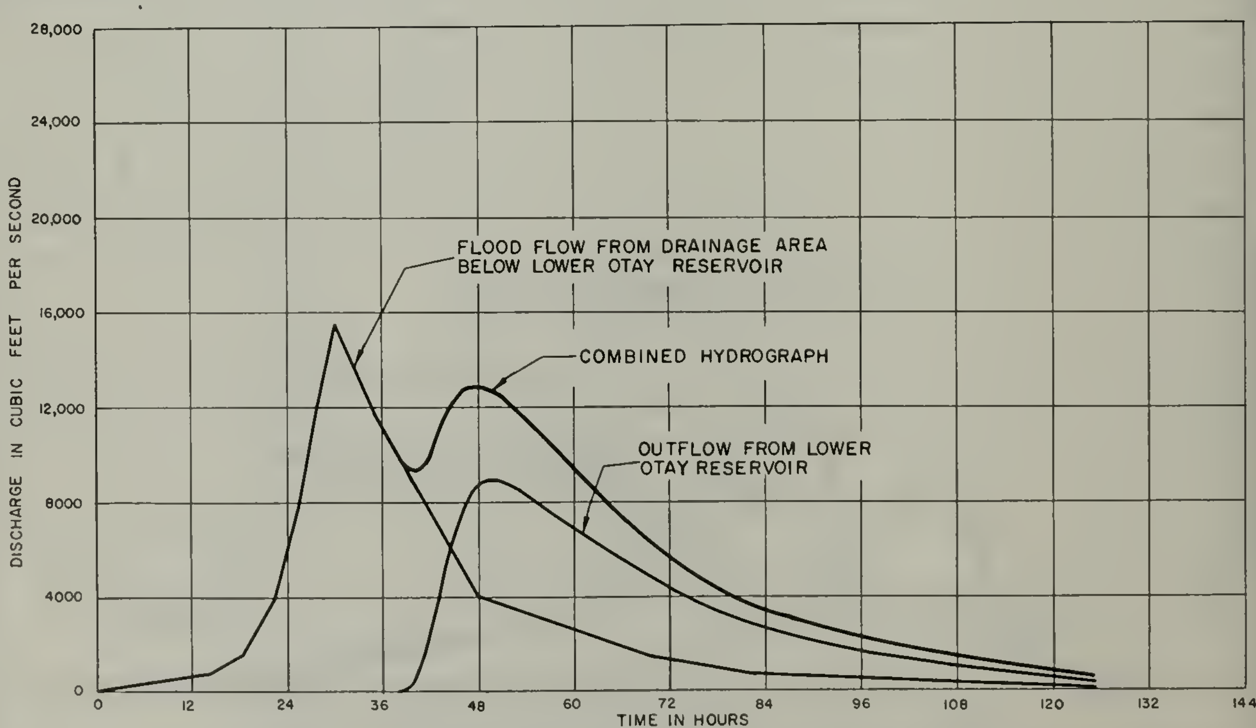
FLOOD HYDROGRAPH AT STREAM MILE 6.5 OF OTAY RIVER
FOR 100-YEAR FLOOD
ASSUMING HALF-FULL RESERVOIR CONDITIONS

FIGURE E-13



FLOOD HYDROGRAPH AT MOUTH OF OTAY RIVER
FOR 50-YEAR FLOOD
ASSUMING HALF-FULL RESERVOIR CONDITIONS

FIGURE E-14



FLOOD HYDROGRAPH AT MOUTH OF OTAY RIVER
FOR 100-YEAR FLOOD
ASSUMING HALF-FULL RESERVOIR CONDITIONS

TABLE 2

ESTIMATED TOTAL PEAK FLOOD DISCHARGES FOR SELECTED LOCATIONS ON THE OTAY RIVER, ASSUMING FULL RESERVOIR CONDITIONS

In cubic feet per second

Location	Routed spills from Lower Otay Reservoir	Flood discharges from area below Lower Otay Reservoir	Total peak discharges
	50-year Flood		
At San Diego and Eastern R.R. Bridge	15,600	8,300	23,900
Confluence of Poggi Canyon and Otay River	16,100	6,200	22,300
Stream mile 6.5 from mouth	16,200	5,400	21,600
Confluence of Wolf Canyon and Otay River	16,200	4,600	20,800
Approx. 1,500 feet downstream from confluence of Johnson Canyon and Otay River	16,200	3,300	19,500
	100-year Flood		
At San Diego and Eastern R.R. Bridge	22,200	11,000	33,200
Confluence of Poggi Canyon and Otay River	22,200	8,700	30,900
Stream mile 6.5 from mouth	22,200	7,600	29,800
Confluence of Wolf Canyon and Otay River	22,500	5,900	28,400
Approx. 1,500 feet downstream from confluence of Johnson Canyon and Otay River	22,500	4,100	26,600

for the assumed condition of reservoirs full initially. It will be noted that the partial discharges tabulated for each area contributing to the peak discharge are the discharges taken from the individual hydrographs directly below the maximum discharge on the combined hydrograph, and that this value may not be the maximum discharge for the smaller hydrographs due to the influence of lag time.

CHAPTER III. AREAS OF POTENTIAL INUNDATION

This chapter describes the final step in the study--determination of the areas of potential inundation along the Otay River from Savage Dam (Lower Otay Reservoir) to the river mouth for 50-and 100-year floods. The study was conducted for two different assumed reservoir conditions: (1) both Upper Otay and Lower Otay Reservoirs initially full, and (2) both Upper Otay and Lower Otay Reservoirs one-half full initially.

Backwater Curve Computations

By use of Equation 9 in Appendix B, backwater curves were computed for discharges ranging from 35,000 to 5,000 cubic feet per second for the reach of the Otay River under investigation (between Savage Dam and the river mouth). This range of discharges included the flood peaks presented in Tables 1 and 2. A total of 41 cross sections were selected on the 11-mile-long reach of the Otay River. The distance between cross sections varied from about 400 to about 2,600 feet, with the average distance being about 1,450 feet. The roughness coefficient, n, in the Manning formula, varied from 0.030 to 0.045. The energy coefficient, α, varied from 1.0 to 1.9, with the average being about 1.2.

For approximately six miles of the Otay River just downstream from Savage Dam, cross sections were obtained from U. S. Geological Survey 7.5 minute quadrangle sheets due to the unavailability of large-scale topographic maps.

In certain portions of the river, the flows were found to be supercritical due to the steep channel slope. In these locations, the backwater curves were computed by assuming critical depth at the upstream break in slope. A straight line variation in water surface was assumed between the breaks in slopes. In the uppermost reaches between Savage Dam and approximately two miles downstream from Savage Dam, the flow was in the supercritical region and was assumed to be at normal depth, as discussed in Appendix B.

Use of the standard step method of backwater computations requires the establishment of an initial water-surface elevation at the beginning of calculations. The backwater computations were carried upstream from Montgomery Freeway Bridge, approximately two miles upstream from San Diego Bay, by assuming the water-surface elevation immediately downstream of the bridge to be at critical depth (no backwater). Between the bridge and the bay, the river crosses a wide flat area which has no definite channel section. It was assumed that the flat area adjacent to the bay would not create a backwater effect downstream of the bridge. The effect of backwater due to the bridge was considered to establish the water-surface elevation upstream of the bridge. Backwater computations were then carried upstream as stated, starting from the upstream water-surface elevation at the bridge section.

Stage-Discharge Curves

As stated, backwater curves were computed for discharges ranging from 35,000 to 5,000 cubic feet per second for the reach under investigation. Stage-discharge curves were plotted at selected points along the Otay River from the results of the backwater curve computations. Typical stage-discharge curves for the Otay River approximately 2,000 feet upstream from the National Avenue Bridge and approximately 6.5 miles upstream from the river mouth are shown on Figure E-15. These curves were then used to determine the stage at selected points for the computed peak discharge as shown in Tables 1 and 2.

Water-Surface Profiles

From the peak discharges presented in Tables 1 and 2 and the stage-discharge curves for particular points on the stream, the water-surface elevations were determined and the water-surface profiles drawn. A straight line variation in the water-surface profiles was assumed between any two successive sections where the stage-discharge relationship was derived. A total of 41 points along the Otay River below Savage Dam were utilized in determining the water-surface profiles.

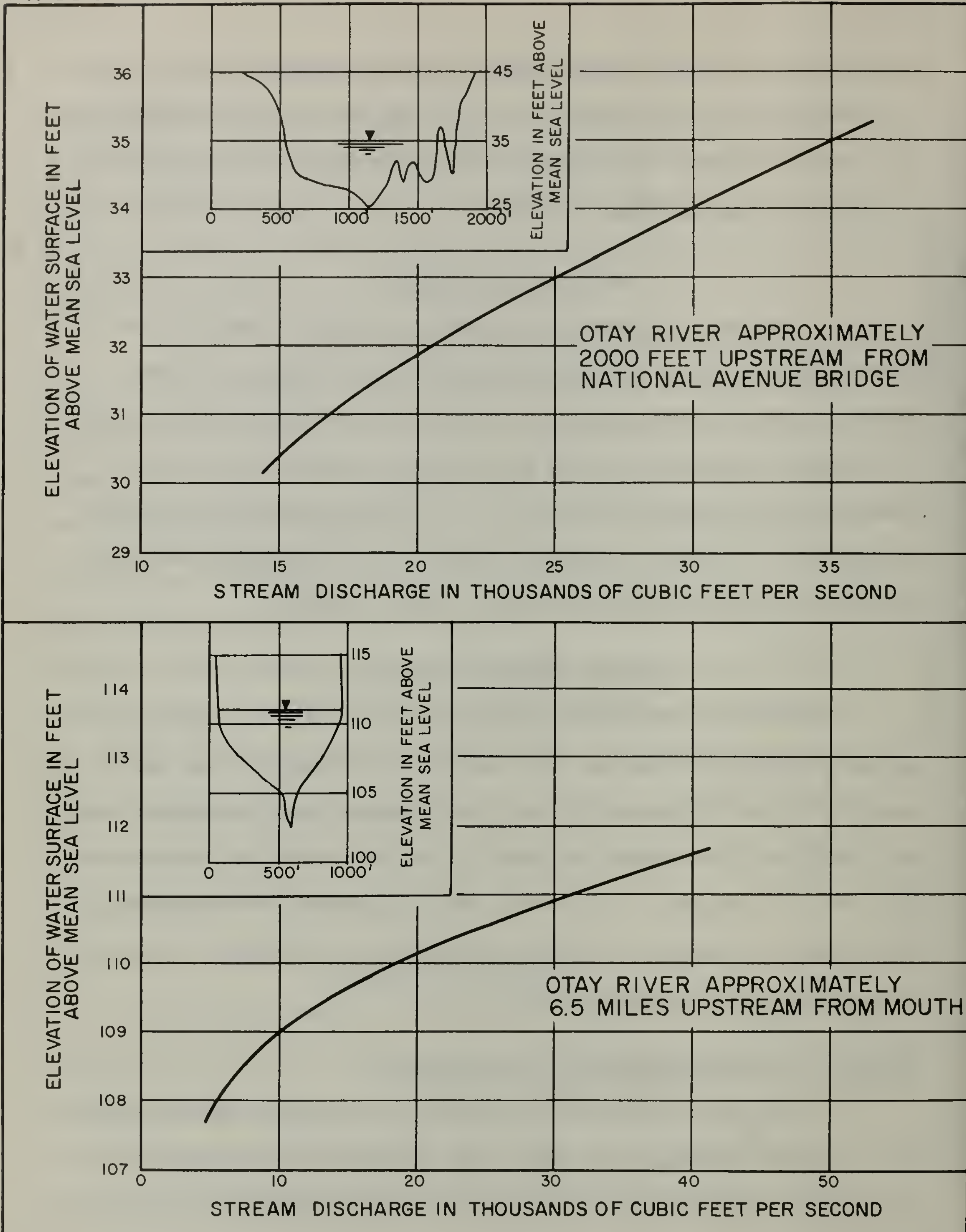
Areas of Potential Inundation

From the water-surface profiles, the elevations of the flood waters at any point along the river could be ascertained. Areas which would be subject to inundation were then delineated upon topographic maps at a scale of 1 inch equals 200 feet, for all but six miles of river channel. For the remainder of the river, and for purposes of presentation in this report, the areas of potential inundation were delineated on plates at a scale of 1 inch equals 2,000 feet.

Condition of Reservoirs One-Half Full Initially

The areas of potential inundation for a flood of 100-year recurrence interval, assuming both Upper Otay and Lower Otay Reservoirs are one-half full initially, are illustrated on Plates E-2A and 2B. For the

FIGURE E-15



TYPICAL STREAM CROSS SECTIONS
AND STAGE DISCHARGE CURVES

flood of 50-year recurrence interval (not shown) the area inundated closely parallels the lines delineated for the 100-year flood. The average difference in depth of flow between a 50- and a 100-year flood was about 1.3 feet for the entire reach.

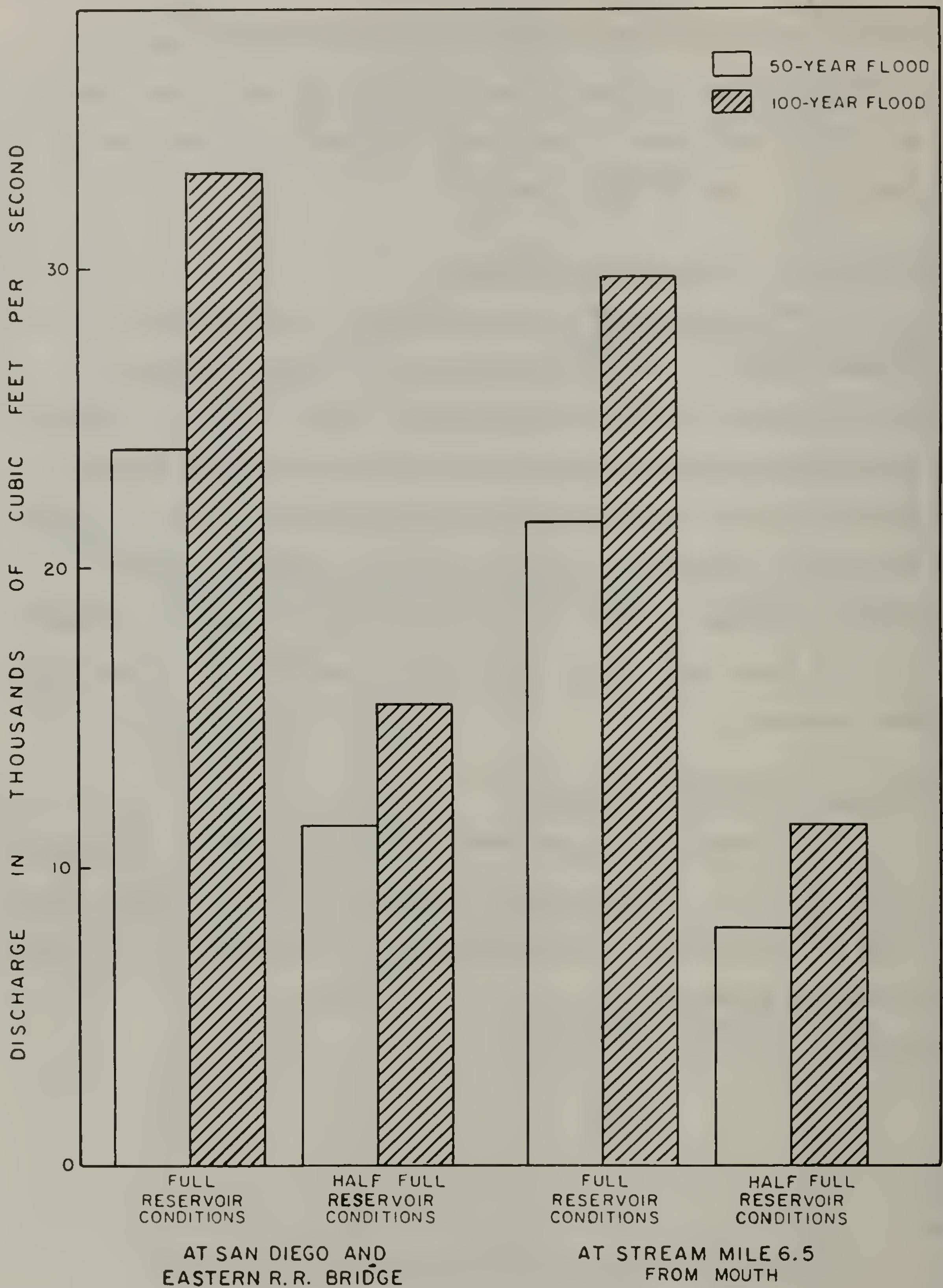
Condition of Reservoirs Full Initially

The areas of potential inundation for 50- and 100-year floods, assuming Upper Otay and Lower Otay Reservoirs are full initially, are shown on Plates E-3A and 3B. Although the 100-year flood is considerably larger than the 50-year flood and the attenuating effect of the full reservoir is less significant, the areas inuundated by a 50- and 100-year flood closely parallel each other. This small difference in depth, an average difference of about 1.3 feet for the entire reach, can be attributed to a large extent to the wide uniform channels in all but the extreme upper reaches.

Summary of Peak Flood Discharges

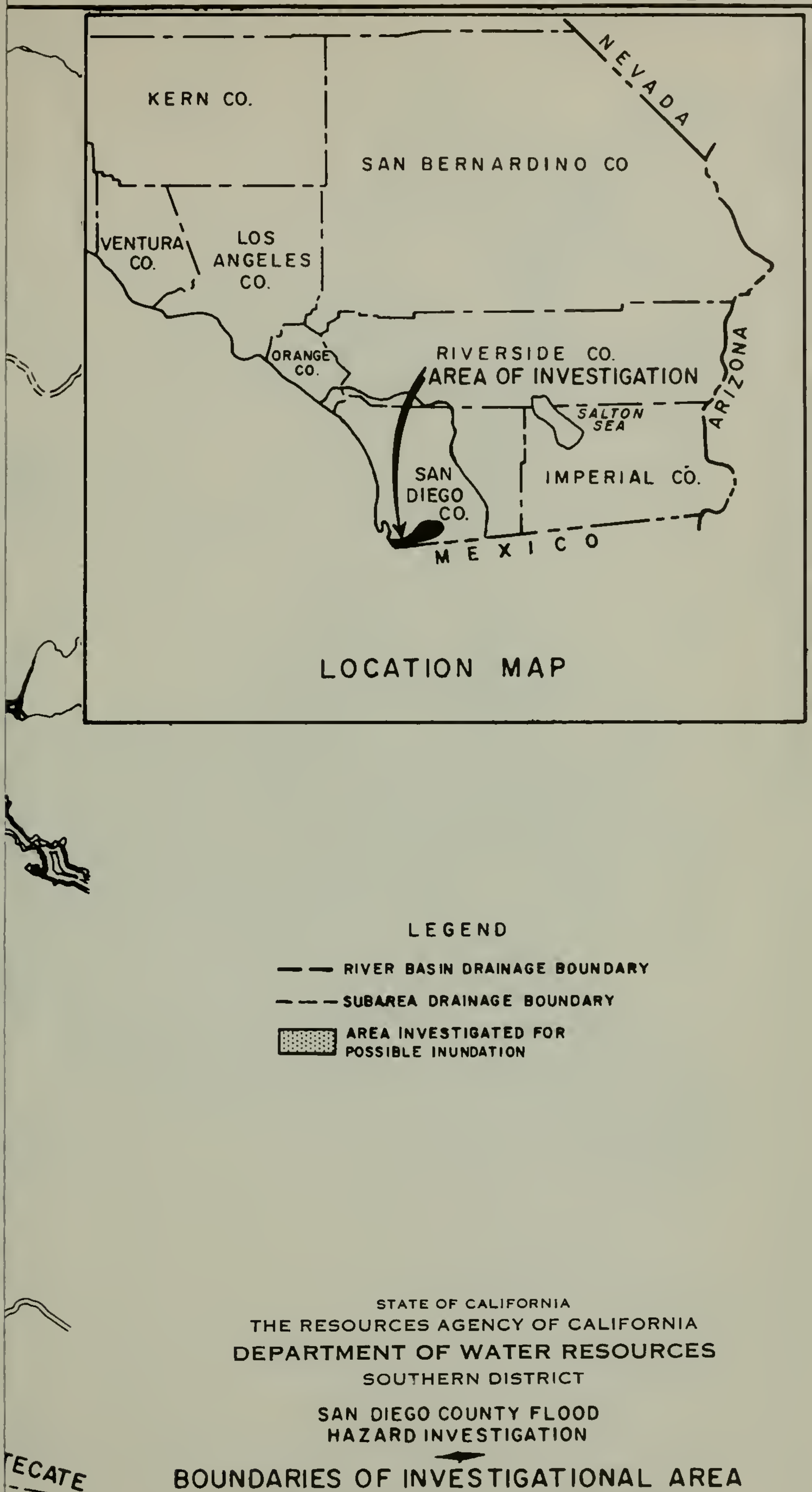
A summary of the peak flood discharges for the 50- and 100-year floods at selected locations along the Otay River for the assumed conditions of reservoirs full initially and reservoirs one-half full initially, is shown in Figure E-16.

FIGURE E-16



SUMMARY OF PEAK FLOOD DISCHARGES AT SELECTED LOCATIONS ON THE OTAY RIVER

DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1964



LEGEND

RIVER BASIN DRAINAGE BOUNDARY

SUBAREA DRAINAGE BOUNDARY

AREA INVESTIGATED FOR POSSIBLE INUNDATION

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

BOUNDARIES OF INVESTIGATIONAL AREA WITHIN OTAY RIVER BASIN

SCALE OF MILES

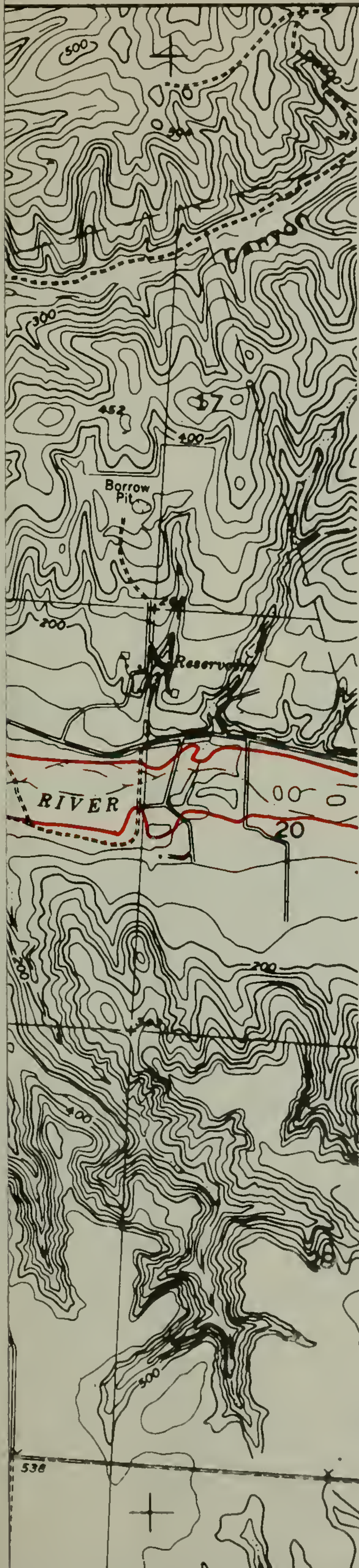
1 0 1 2 3

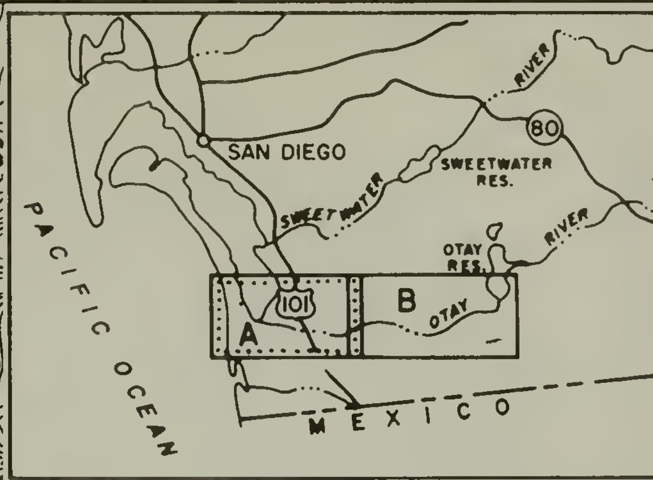
1964

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

BOUNDARIES OF INVESTIGATIONAL AREA WITHIN OTAY RIVER BASIN





KEY MAP

LEGEND

INUNDATED AREA FOR 50 AND 100 YEAR FLOODS

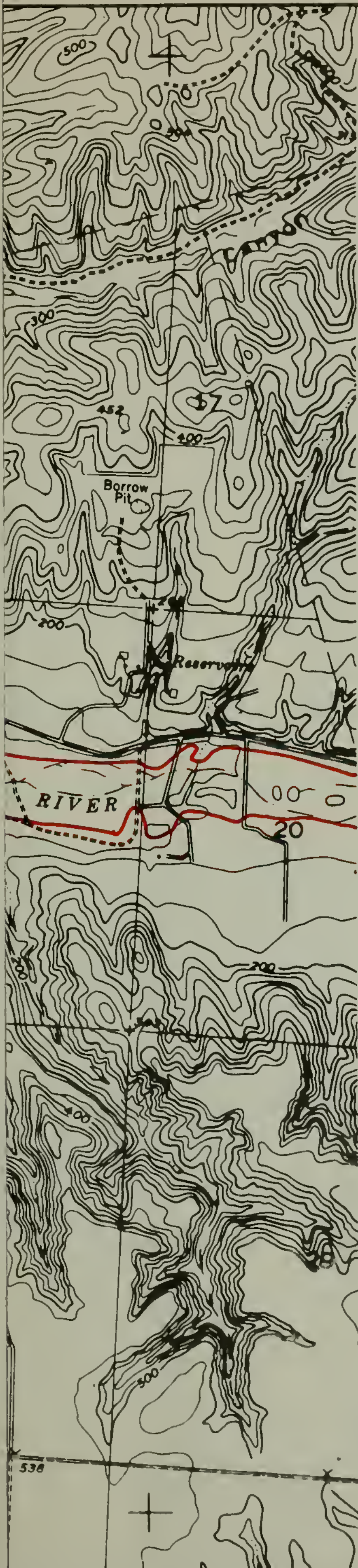
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

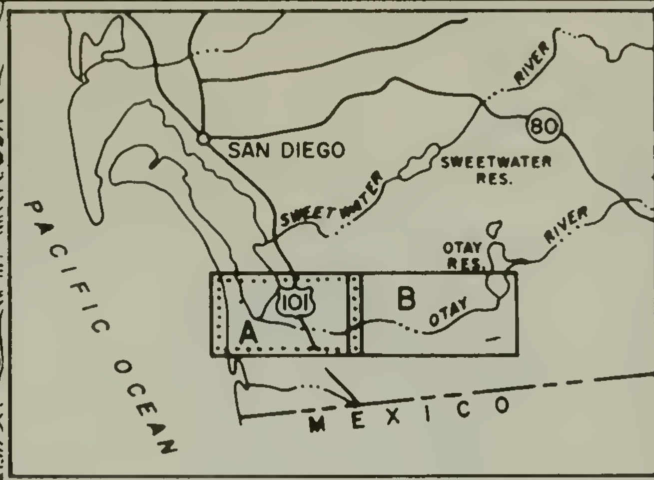
OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET

1000 0 1000 2000

1964





KEY MAP

LEGEND

INUNDATED AREA FOR 50 AND 100 YEAR FLOODS

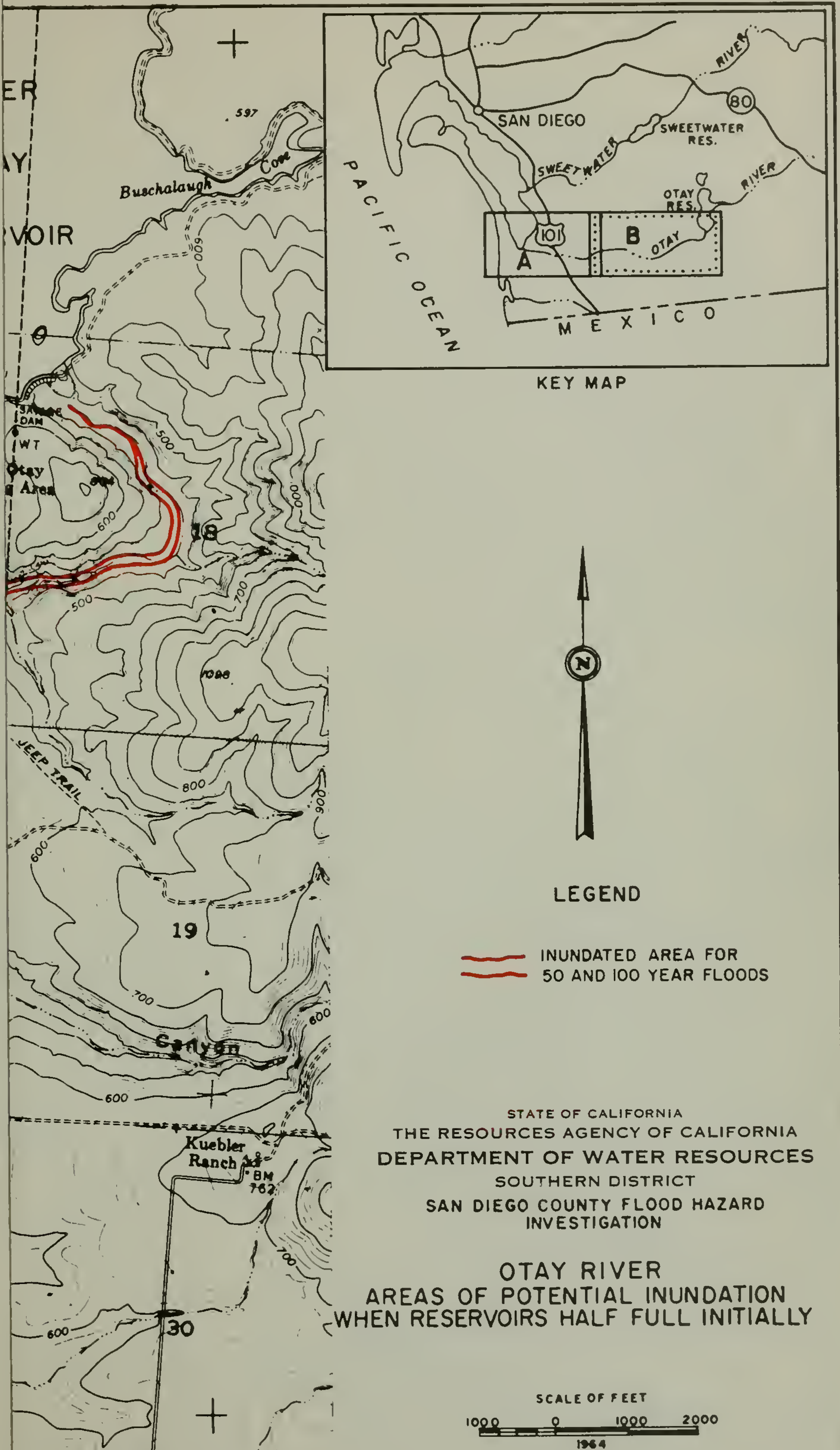
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964

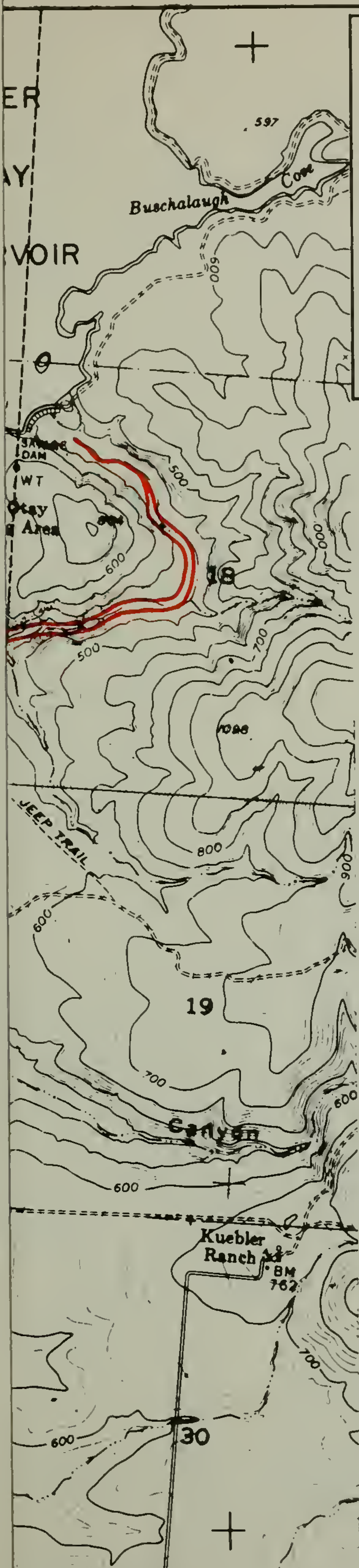
PLATE E-2A

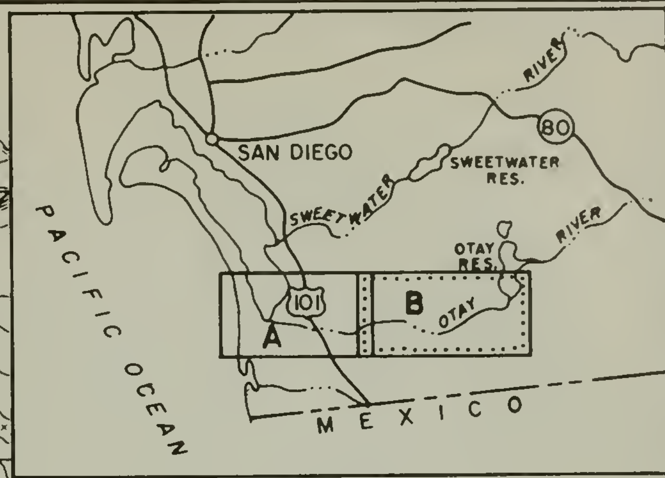
KEY MAP
SAN DIEGO
PACIFIC OCEAN
MEXICO
SWEETWATER RES
OTAY RES
LEGEND
INUNDATED AREA FOR 50 AND 100 YEAR FLOODS
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION
OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS HALF FULL INITIALLY
SCALE OF FEET
1000 0 1000 2000
SAN DIEGO BAY
SALT EVAPORATORS
NAVAL RADIO STATION
Coronado Heights
Imperial Beach
Palm City
Otay
OTAY VALLEY
OTAY RIVER
Harbor Side
Castle Park
Fruitdale
Nestor
REAM FIELD
NAVAL AUXILIARY AIR STATION
Mar Vista High School
Emory School
Southwest Jr H.S.
Judson Res
Montgomery Sch



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

OTAY RIVER
AREAS OF POTENTIAL INUNDATION WHEN RESERVOIRS HALF FULL INITIALLY





KEY MAP

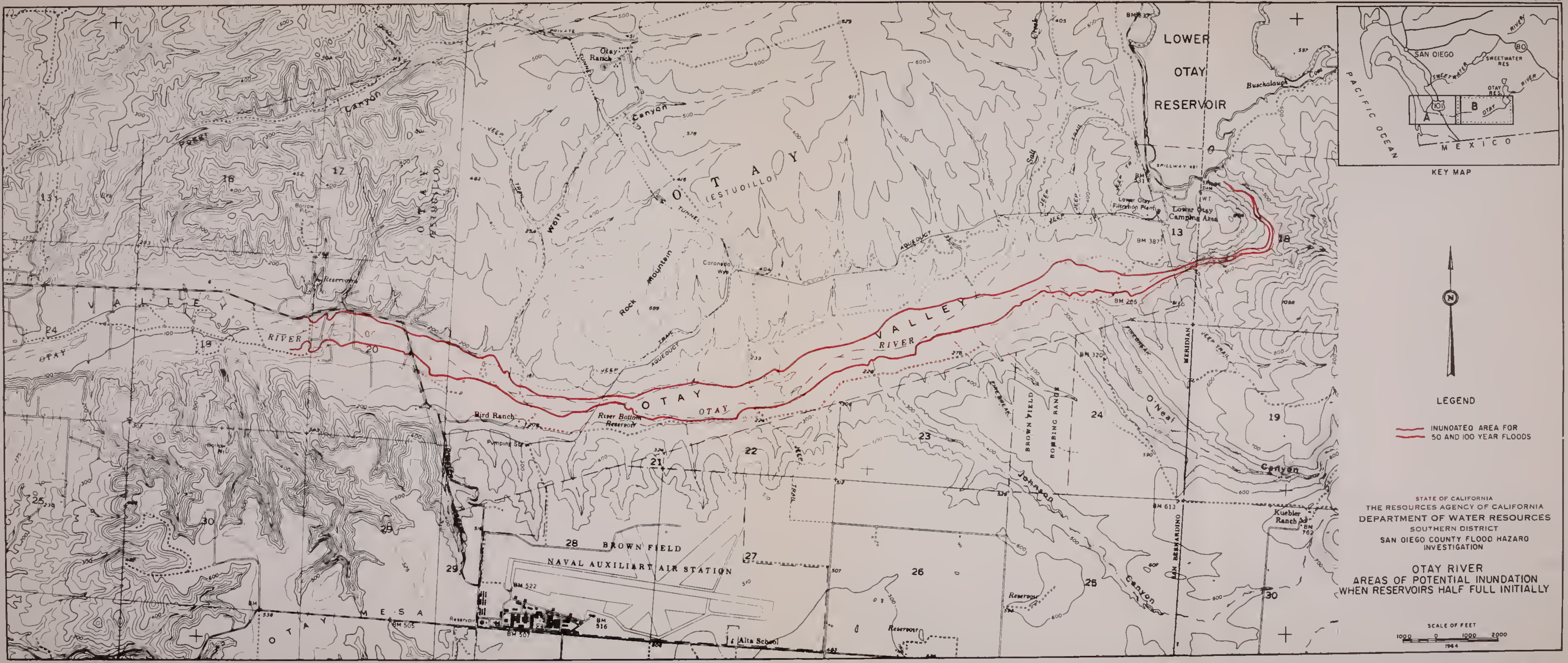
LEGEND

INUNDATED AREA FOR
50 AND 100 YEAR FLOODS

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964



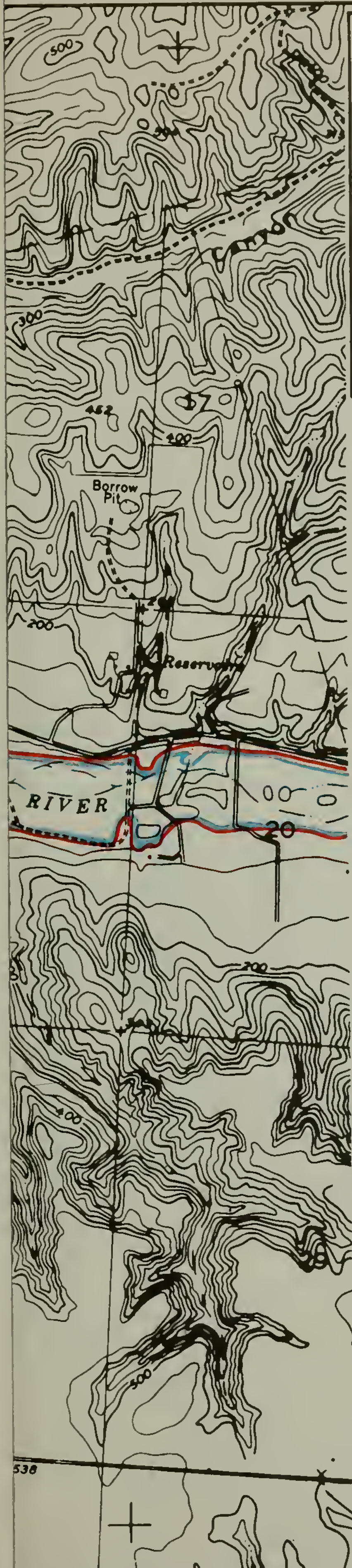
LEGEND

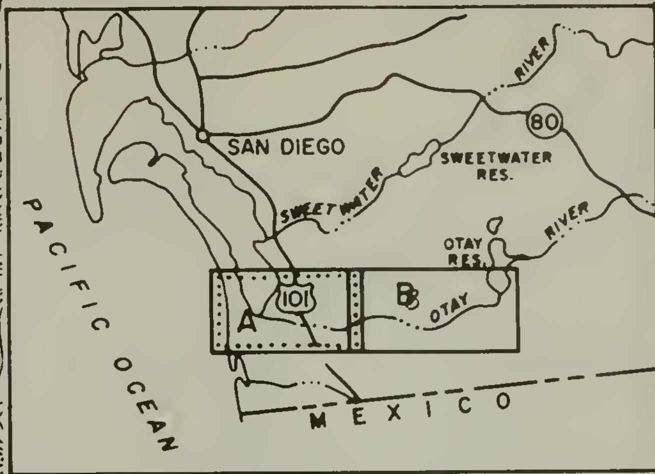
INUNDATED AREA FOR 50 AND 100 YEAR FLOODS

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964





KEY MAP

LEGEND

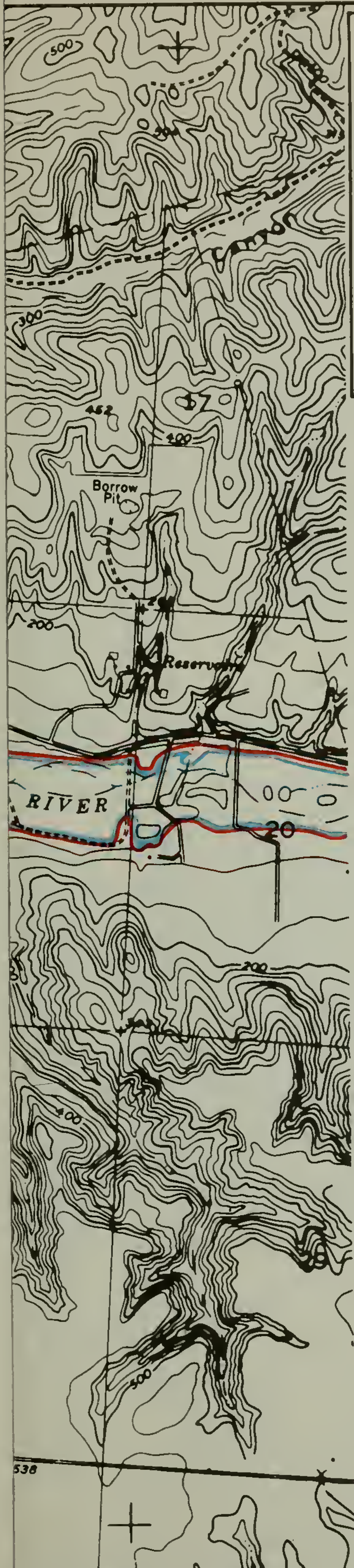
INUNDATED AREA FOR 100 YEAR FLOOD

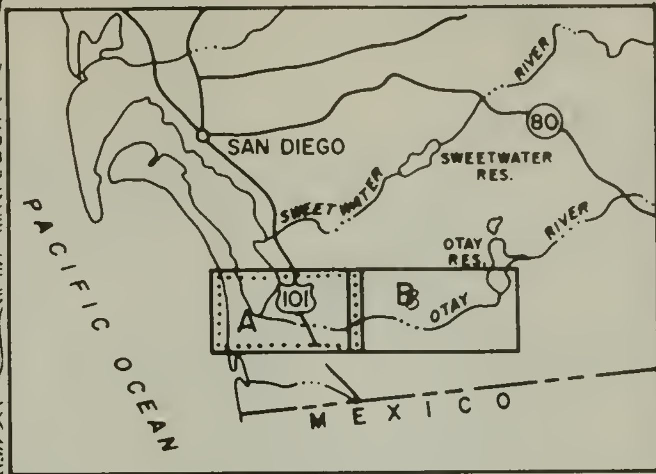
INUNDATED AREA FOR 50 YEAR FLOOD

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964





KEY MAP

LEGEND

INUNDATED AREA FOR 100 YEAR FLOOD

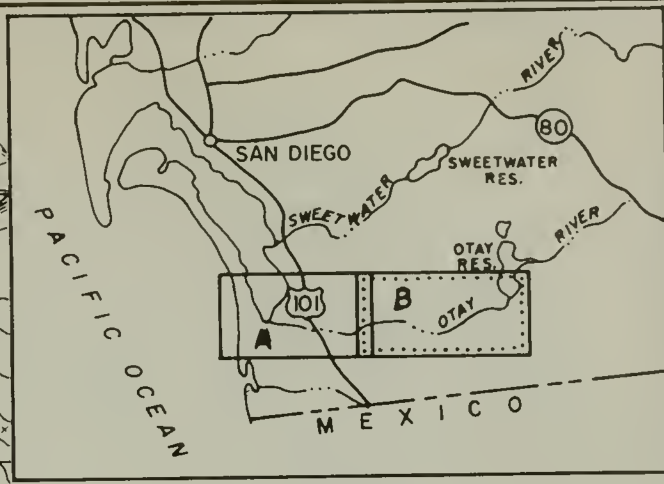
INUNDATED AREA FOR 50 YEAR FLOOD

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

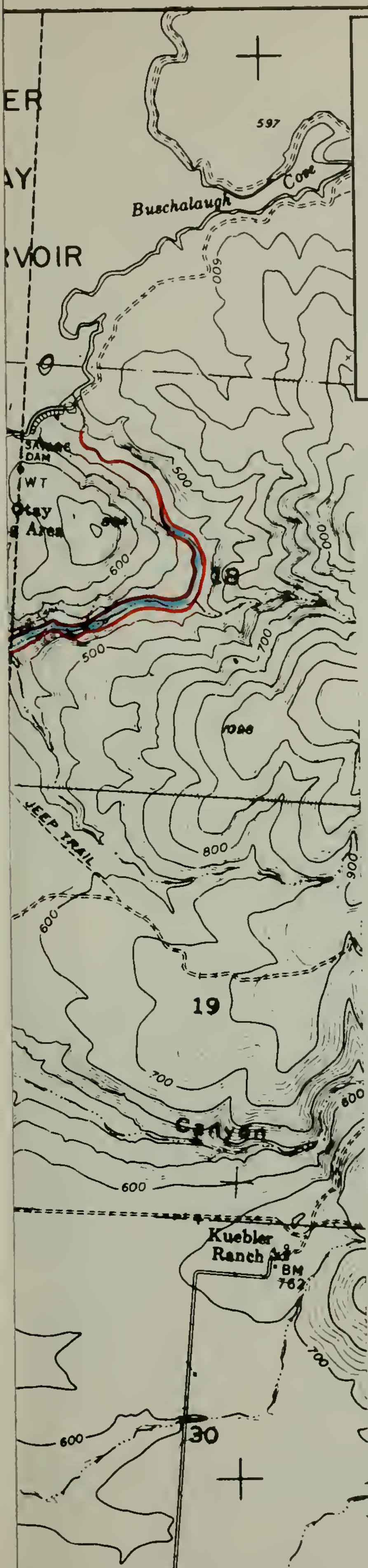
OTAY RIVER
AREAS OF POTENTIAL INUNDATION WHEN RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964


SAN DIEGO BAY
SALT EVAPORATORS
Coronado Heights
NAVAL RADIO STATION
Harbor Side
Castle Park
Fruitdale
Otay
OTAY RIVER
Palm City
Nestor
Emory School
Mar Vista High School
Southwest Jr H S
REAM FIELD
NAVAL AUXILIARY AIR STATION
Judson Res
FREEWAY
KEY MAP
SAN DIEGO
PACIFIC OCEAN
SWEETWATER RES.
OTAY RES.
MEXICO
LEGEND
INUNDATED AREA FOR 100 YEAR FLOOD
INUNDATED AREA FOR 50 YEAR FLOOD
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION
OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS FULL INITIALLY
SCALE OF FEET
1000 0 1000 2000
1964



KEY MAP



LEGEND

INUNDATED AREA FOR 100 YEAR FLOOD

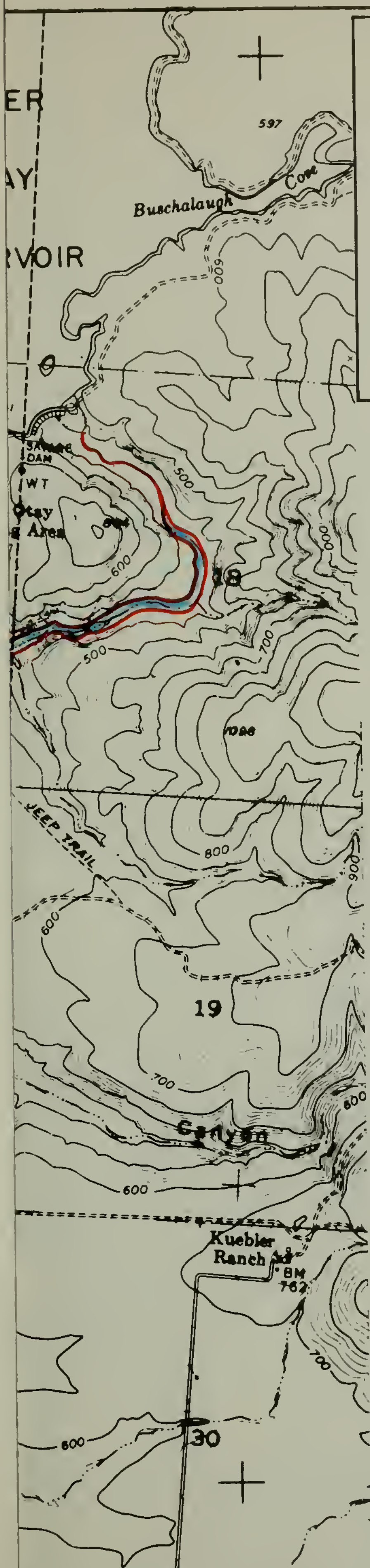
INUNDATED AREA FOR 50 YEAR FLOOD

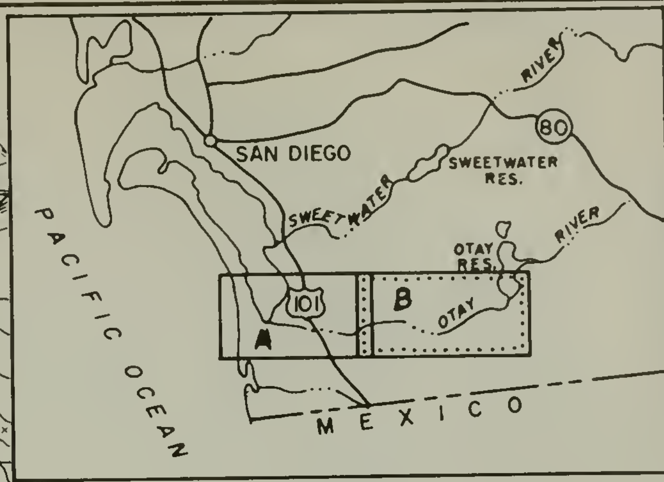
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964





KEY MAP

LEGEND

INUNDATED AREA FOR 100 YEAR FLOOD

INUNDATED AREA FOR 50 YEAR FLOOD

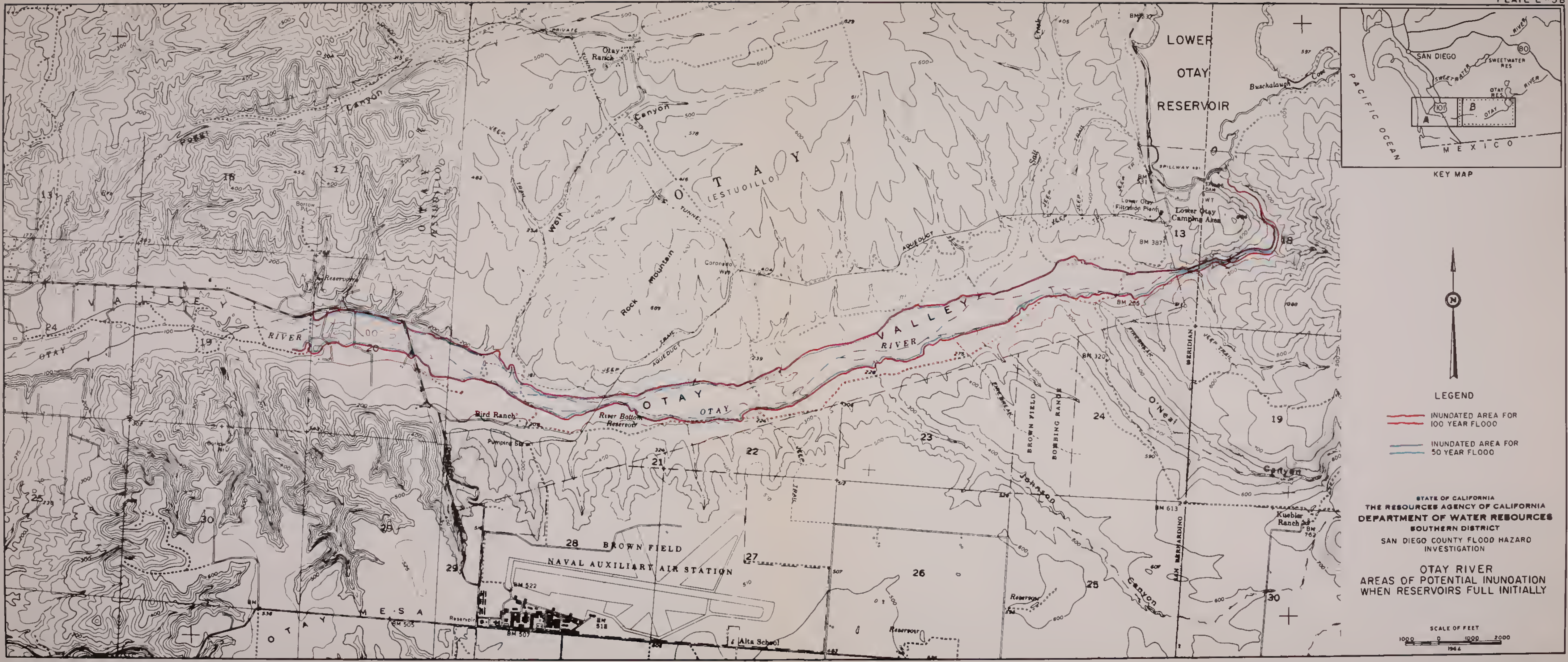
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

OTAY RIVER
AREAS OF POTENTIAL INUNDATION WHEN RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000
1964

PLATE E-3B


KEY MAP
SAN DIEGO
SWEETWATER RES
OTAY RES
PACIFIC OCEAN
MEXICO
LEGEND
INUNDATED AREA FOR 100 YEAR FLOOD
INUNDATED AREA FOR 50 YEAR FLOOD
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
SOUTHERN DISTRICT
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION
OTAY RIVER
AREAS OF POTENTIAL INUNDATION
WHEN RESERVOIRS FULL INITIALLY
SCALE OF FEET
1000 0 1000 2000
1964
LOWER OTAY RESERVOIR
OTAY VALLEY
OTAY RIVER
Rock Mountain
Lower Otay Filtration Plant
Lower Otay Camping Area
Bird Ranch
River Bottom Reservoir
BROWN FIELD NAVAL AUXILIARY AIR STATION
OTAY MESA
Alta School
O'Neal Canyon
Johnson Canyon
Kuebler Ranch

APPENDIX F

AREAS OF POTENTIAL FLOOD INUNDATION
SAN DIEGUITO RIVER BASIN, CALIFORNIA

(Prepared by U. S. Geological Survey)

APPENDIX F

AREAS OF POTENTIAL FLOOD INUNDATION
SAN DIEGUITO RIVER BASIN, CALIFORNIA

(Prepared by U. S. Geological Survey)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

AREAS OF POTENTIAL FLOOD INUNDATION
SAN DIEGUITO RIVER BASIN, CALIFORNIA

by

L. E. Young and H. A. Ray

APPENDIX F
TO
BULLETIN 112
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

State of California
Department of Water Resources

July 1963

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ILLUSTRATIONS

(Plates 1 to 4-E are bound at end of report)

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TABLES

INTRODUCTION

Purpose and Scope

This report (Appendix F to State of California Department of Water Resources Bulletin 112 - San Diego County Flood Hazard Investigation) is part of a project to investigate the flood hazard along flood plains of the five major rivers in San Diego County, California (fig. 1). The purpose of this report is to provide information on the flood hazard along the San Dieguito River. Similar reports are being prepared for the San Luis Rey River, San Diego River, Otay River, and Sweetwater River.

There were two basic parts to this study. The first was the determination of peak discharge at key sites along the river for floods of two selected frequencies, namely, the 50-year flood and 100-year flood. As used in this report, a 50-year flood is defined as a flood with a 2 percent probability of being equaled or exceeded in any year. A 100-year flood is similarly defined as having a 1 percent probability of being equaled or exceeded in any year. Reservoir flood routing methods were used to determine the effect of existing reservoirs in attenuating the peak discharge of these hypothetical floods. The second part was the determination of the water-surface profile for both floods using topographic data from field surveys and large-scale county maps. The surface-water profiles were used to define areas of potential inundation.

The report is a source of flood information that provides a basis for establishing criteria to control encroachment on the San Dieguito River flood plain. Areas subject to periodic inundation are delineated on 7½ minute quadrangle maps included with this report.

The data and computations upon which this report is based are available in the files of the U.S. Geological Survey, Menlo Park, California. The study was made under the general direction of Walter Hofmann, district engineer, in charge of surface-water investigations in California, with technical assistance by S. E. Rantz.

FIGURE I

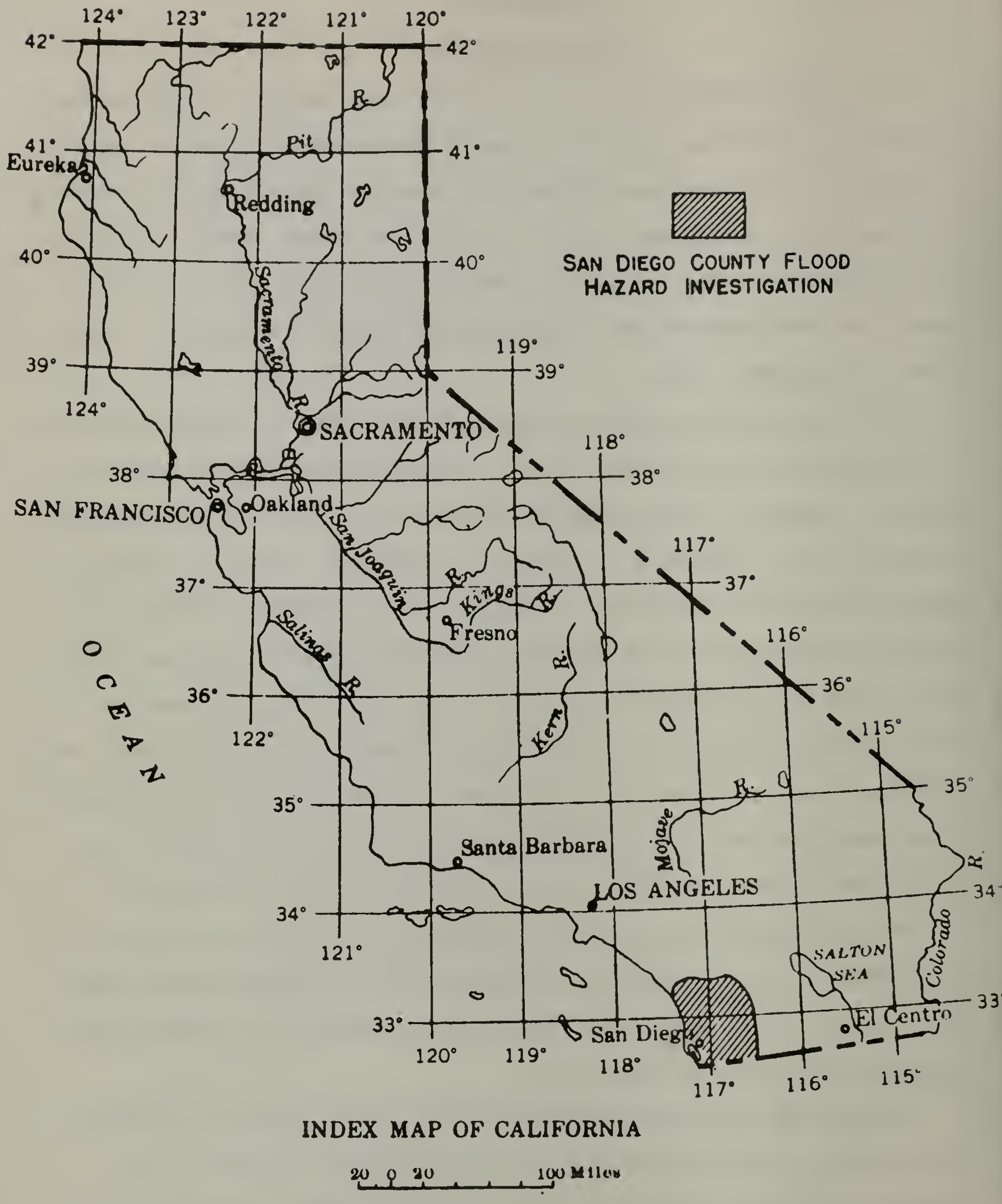


Figure 1.--Location of project area

Acknowledgments

The study described in this report was authorized by a cooperative agreement between the U.S. Geological Survey and California Department of Water Resources for the investigation of the flood hazard on two major rivers in San Diego County. The assistance of the California Department of Water Resources in processing the data for reservoir routing studies, providing a field survey crew, and printing the maps for this report is gratefully acknowledged. The helpful cooperation of the county of San Diego, Department of Special District Services, is also acknowledged.

Description of the Area

The San Dieguito River system lies in the central part of San Diego County with headwaters in the Volcan Mountains on the western slope of the Coast Range. The main stem of the river, which is formed by the confluence of Santa Ysabel and Santa Maria Creeks in the vicinity of San Pasqual, flows westward through San Pasqual Valley and discharges into the Pacific Ocean at the city of Del Mar. Total stream length is about 53 miles and maximum width of drainage basin is about 15 miles. The drainage area of the San Dieguito River basin is approximately 346 square miles. It is bounded on the north by San Luis Rey River basin and on the south by the San Diego River basin. Altitudes in the basin range from near sea level on the west to about 5,700 feet above sea level at the eastern drainage divide. The basin has very few trees, the principal cover being grass and brush. The mean annual rainfall varies from 10 inches along the foothills to slightly more than 30 inches on the mountain slopes.

PEAK FLOOD FLOWS

Regional Flood Frequency

A regional flood-frequency analysis to define the relation between the magnitude and frequency of momentary annual peak flows of streams in the project area was made by the California Department of Water Resources and reviewed by the Geological Survey. The regional concept of flood-frequency analysis was adapted because flood-frequency relations derived from the combined experience of a number of gaging stations in a homogeneous area are considered more reliable than those based on records for individual gaging stations, particularly those with short records. The flood series for any single gaging station is a random sample, and may not be representative of the long-term average distribution of flood events. A regional analysis defines relationships that are applicable to drainage areas of various sizes within a hydrologically homogeneous region. The techniques employed are only briefly discussed here as they are explained in detail in Appendix A to State Bulletin 112.

Analytical Techniques

In a regional analysis of flood-frequency, it is essential that only the flood records for streams whose peak discharge was unaffected by man-made storage or diversion be used. Furthermore, a common length of record, or base period of years, must be used for all gaging stations. Reliability of the analysis depends on the length of the base period as well as on the accuracy of the records. Consequently, the longest base period possible was selected within the period of record of the earliest stations established. The base period chosen was the 55-year period, 1906-60. It was possible to extrapolate the flood-frequency curves beyond the base period because of the availability of qualitative historical records of major floods that occurred prior to 1906.

The methods of tabulating flood data commonly used in flood magnitude-frequency analyses are (1) the annual flood series, and (2) the partial-duration series. The annual series of flood peaks is used in preference to the partial-duration series. Although the partial-duration series is applicable to flood mapping studies, it has been shown (Dalrymple, 1950, p. 6) that the recurrence intervals obtained by the two series approach numerical equality for large floods. For this reason and because of the availability of annual peak data, the annual flood series was used in this study.

Because a common base period is required for all stations, those stations with records shorter than the base period required an estimate of the missing annual peak discharges. These estimates for the stations with short records were made by graphical logarithmic correlation with records for long-term stations that were in operation throughout the base period. In addition to records within the project area, records for nearby stations outside the area were utilized in developing the frequency analysis.

Method of Analysis

The method most commonly used by the Geological Survey in a regional flood-frequency analysis is the index-flood method (Benson, 1962, p. 16). Essentially this method consists of two major steps. The first is the development of basic dimensionless frequency curves representing the ratio of the flood of any frequency to an index flood (generally the mean annual flood). The second step is the development of relations between hydrologic characteristics of drainage areas and the mean annual flood, so that the mean annual flood at any point within the region can be defined. By combining the mean annual flood obtained from the developed relations, with the dimensionless frequency curves, it is then possible to develop a frequency curve for any location.

In a semi-arid region the index-flood method may be inadequate to estimate large flood peaks on the basis of the mean annual flood. This is particularly true of large basins where the mean annual flood may often result from a storm that affects only a part of the basin. An alternate approach (Benson, 1962, p. 20) is a method in which peak flows at selected recurrence intervals are related to hydrologic and physiographic characteristics of the basin by multiple-correlation techniques. This obviates the need of utilizing an index flood, as individual regression equations are derived for each recurrence interval considered. A series of significant drainage basin parameters were tested for their relative significance in predicting flood flows. Briefly, the equations relating the T-year (any recurrence interval) peak discharge, Q_T, to various basin parameters, have the general form:

$$Q_T = a\ B^b C^c D^d\ ---$$

where

B, C, D, -- are the independent variables (basin parameters),

a, b, c, d, --- are constants of the regression equation.

In the project area, it was found that the multiple-correlation technique of flood-frequency analysis gave more satisfactory results than the index-flood method; therefore the multiple-correlation technique was used in this study. After several combinations of basin characteristics were analyzed by multiple regression analyses, those most significant for defining the 50- and 100-year floods for streams in the project area were found to be:

$$Q_{50} = 1016\ A^{.59}\ Sh^{-.44}$$

and

$$Q_{100} = 1288\ A^{.60}\ Sh^{-.57}$$

where

Q_{50} is the 50-year flood discharge, in cubic feet per second

Q_{100} is the 100-year flood discharge, in cubic feet per second

A is the drainage area, in square miles

Sh is a dimensionless basin shape factor.

The shape factor is defined as:

$$Sh = d/l$$

where

d = diameter, in miles, of a circle with an area equal to the basin area

l = length, in miles, of the drainage basin measured parallel to the principal stream channel.

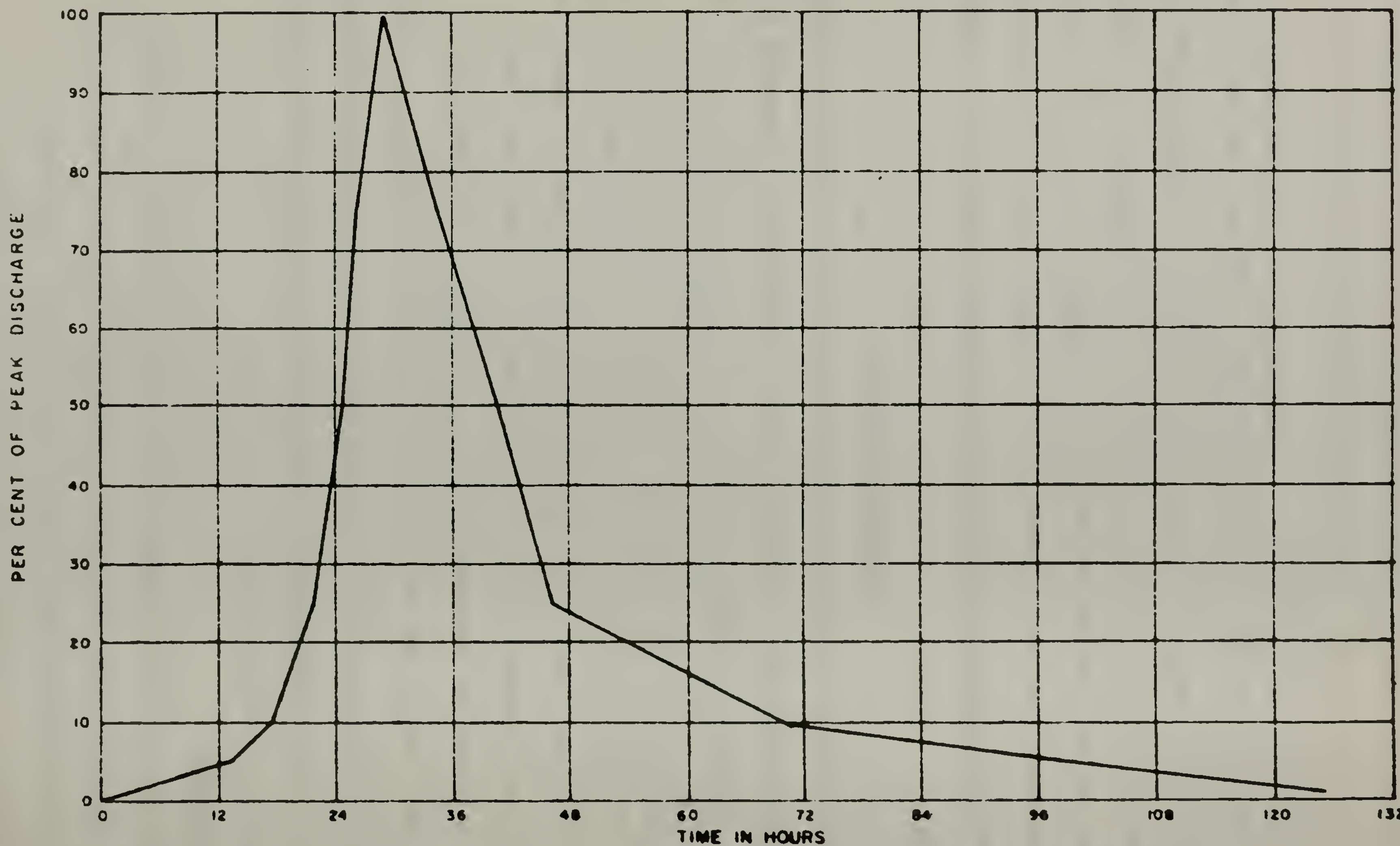
As a convenience to the user determining the 50- or 100-year peak discharges, the results of the two multiple regressions are shown by a family of curves in Appendix A. To use the curves the drainage area above the point for which flood peaks are to be determined and the basin length parallel to the course of the principal stream channel are required. These values can be obtained by planimeter and rule after outlining the appropriate basin area on a topographic map.

Routing Peak Flows

The equations of the previous paragraphs are derived from peak discharges that occurred under natural conditons, that is, uninfluenced by man-made developments in the basin. However, there are major reservoirs in the basin. To determine their effects on peak flows, it was first necessary to obtain a complete hydrograph for a flood event. For the San Dieguito River, as for most rivers in San Diego County, there are few recorded hydrographs of major floods. Therefore it was necessary to utilize flood hydrographs from other rivers in the area. A composite dimensionless flood hydrograph for San Diego County was developed, based on the few available recorded flood hydrographs for all of the major rivers in the area. This hydrograph, which has percent of peak discharge as the ordinate and time elapsed since beginning of storm runoff as the abscissa, is shown in figure 2.

Reservoir Routing

River flows in the San Dieguito River basin are regulated by Sutherland Reservoir (capacity 29,680 acre-feet at spillway elevation) on Santa Ysabel Creek in the upper basin, and by Lake Hodges (capacity 33,550 acre-feet at spillway elevation) in the lower basin, about 12 miles upstream from the



AVERAGE FLOOD HYDROGRAPH FOR SAN DIEGO COUNTY river mouth. There are no large reservoirs on Santa Maria Creek, the other major upstream tributary. The effect of Sutherland Reservoir and Lake Hodges on the 50- and 100-year flood peaks, has been determined by routing these two floods for two conditions of reservoir level, (1) reservoir full at beginning of runoff, and (2) reservoir filled to half capacity at beginning of runoff.

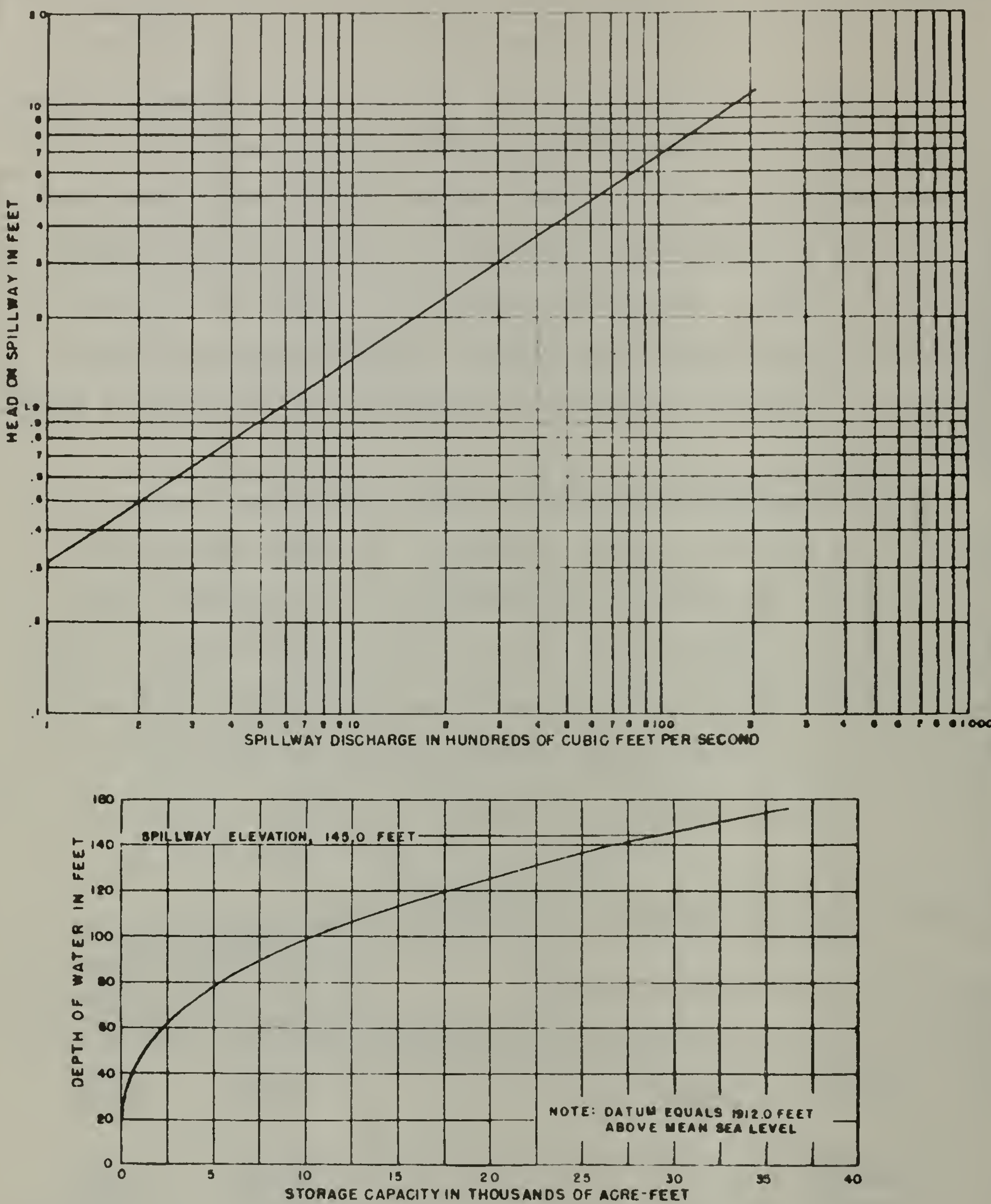
The routing was done by the simple reservoir-storage method (Carter and Godfrey, 1960, p. 102) whereby the storage is assumed to be related solely to the outflow discharge. The only data needed for this method are the inflow hydrograph and the storage-outflow relation. The routing computations were performed by an electronic computer at the Department of Water Resources office in Los Angeles.

Sutherland Reservoir.--The spillway discharge and storage capacity curves for Sutherland Reservoir are given in figure 3. The inflow hydrograph was obtained by using the composite flood hydrograph for the area (fig. 2) and the peak discharges were determined from the regional flood-frequency analysis. Results of the reservoir routing for the 50- and 100-year floods, for the full and half-full reservoir conditions are shown in figure 4. The effect of the reservoir on the peak discharges is summarized in table 1.

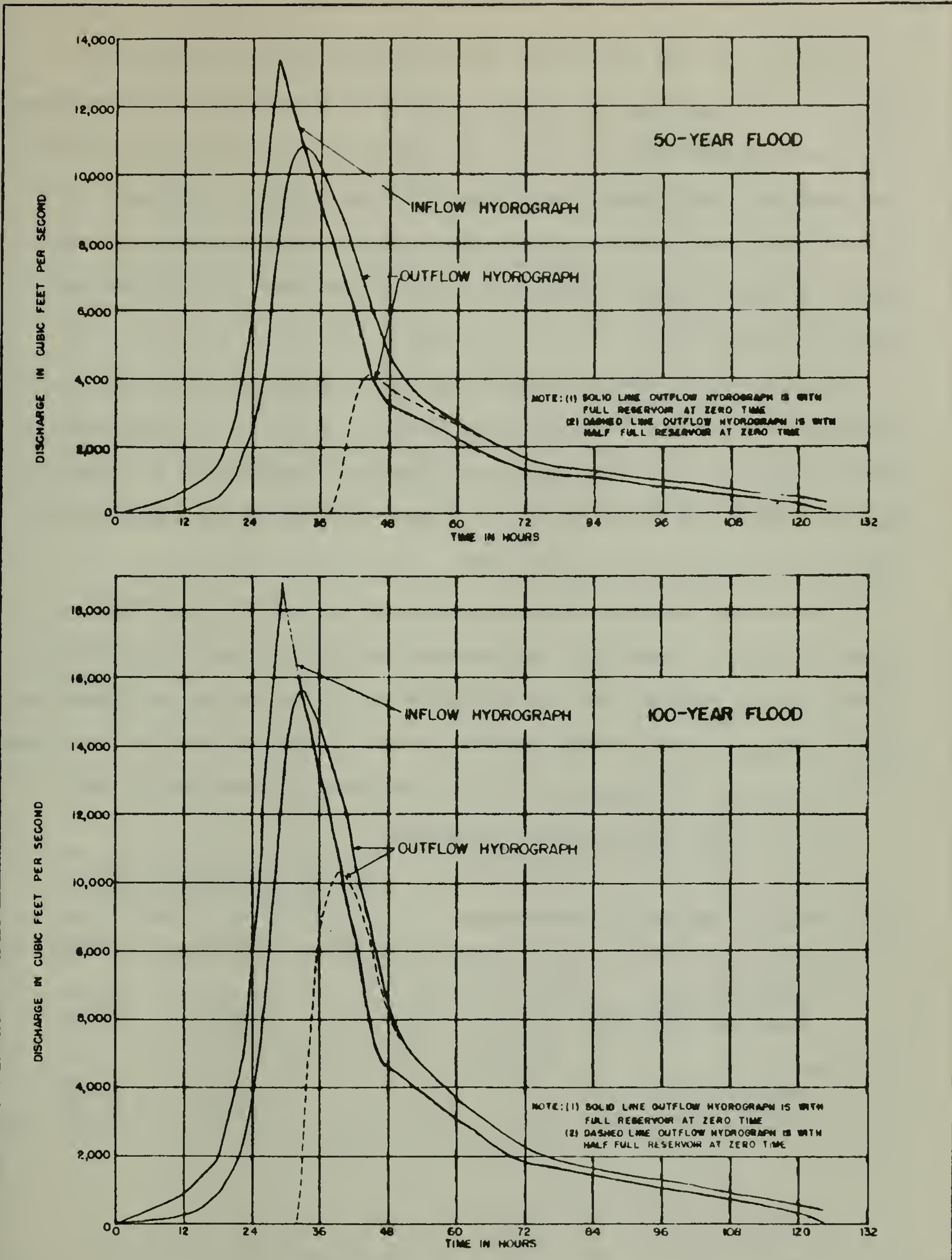
Table 1.--Peak discharges at Sutherland Reservoir

Flood Frequency and Reservoir Condition	Peak Discharge (cubic feet per second)	
	Inflow	Outflow
50-year Flood		
Reservoir full	13,400	10,900
Reservoir half-full	13,400	4,000
100-year Flood		
Reservoir full	18,900	15,700
Reservoir half-full	18,900	10,400

FIGURE 3



SPILLWAY DISCHARGE AND STORAGE CAPACITY CURVES FOR SUTHERLAND RESERVOIR



INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT SUTHERLAND RESERVOIR

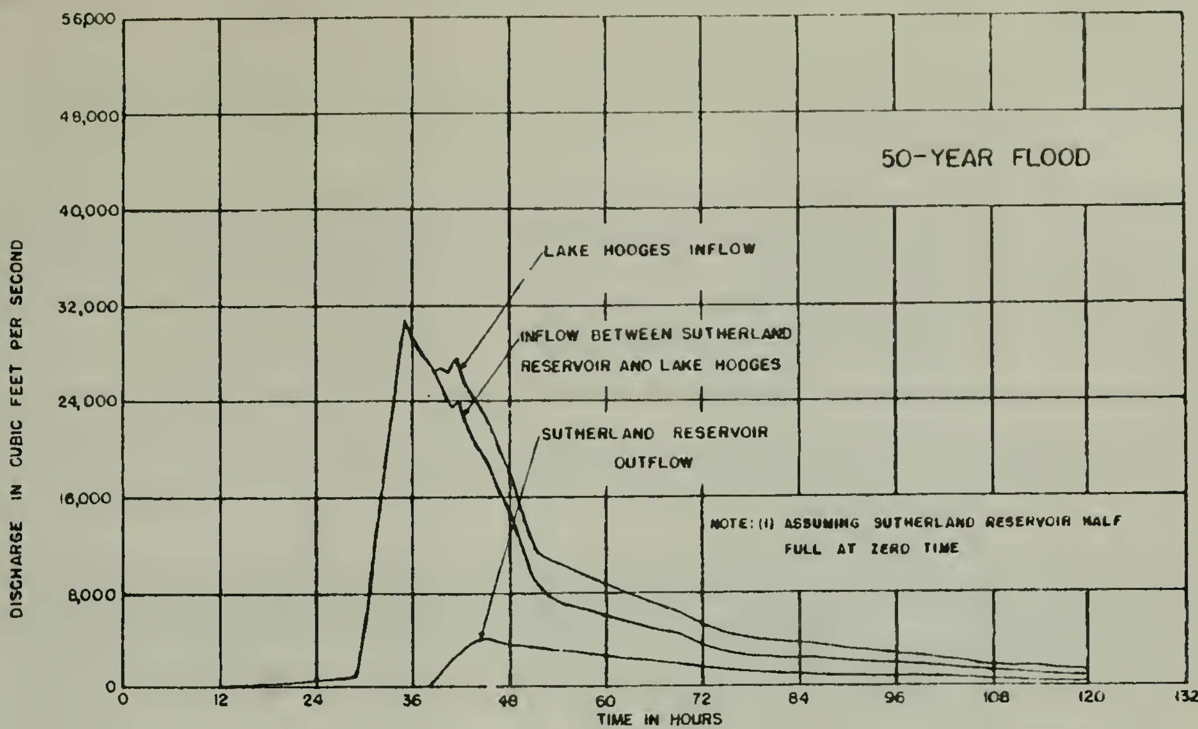
Lake Hodges.--The Lake Hodges inflow hydrographs were adjusted for the effect of Sutherland Reservoir. This was done by determining the inflow between Sutherland Reservoir and Lake Hodges and adding to it the outflow from Sutherland Reservoir with allowance being made for time of travel. Estimates of the time of travel were based on a knowledge of observed travel times on several rivers. The Lake Hodges inflow hydrographs for the condition of Sutherland Reservoir being half-full, are shown in figure 5.

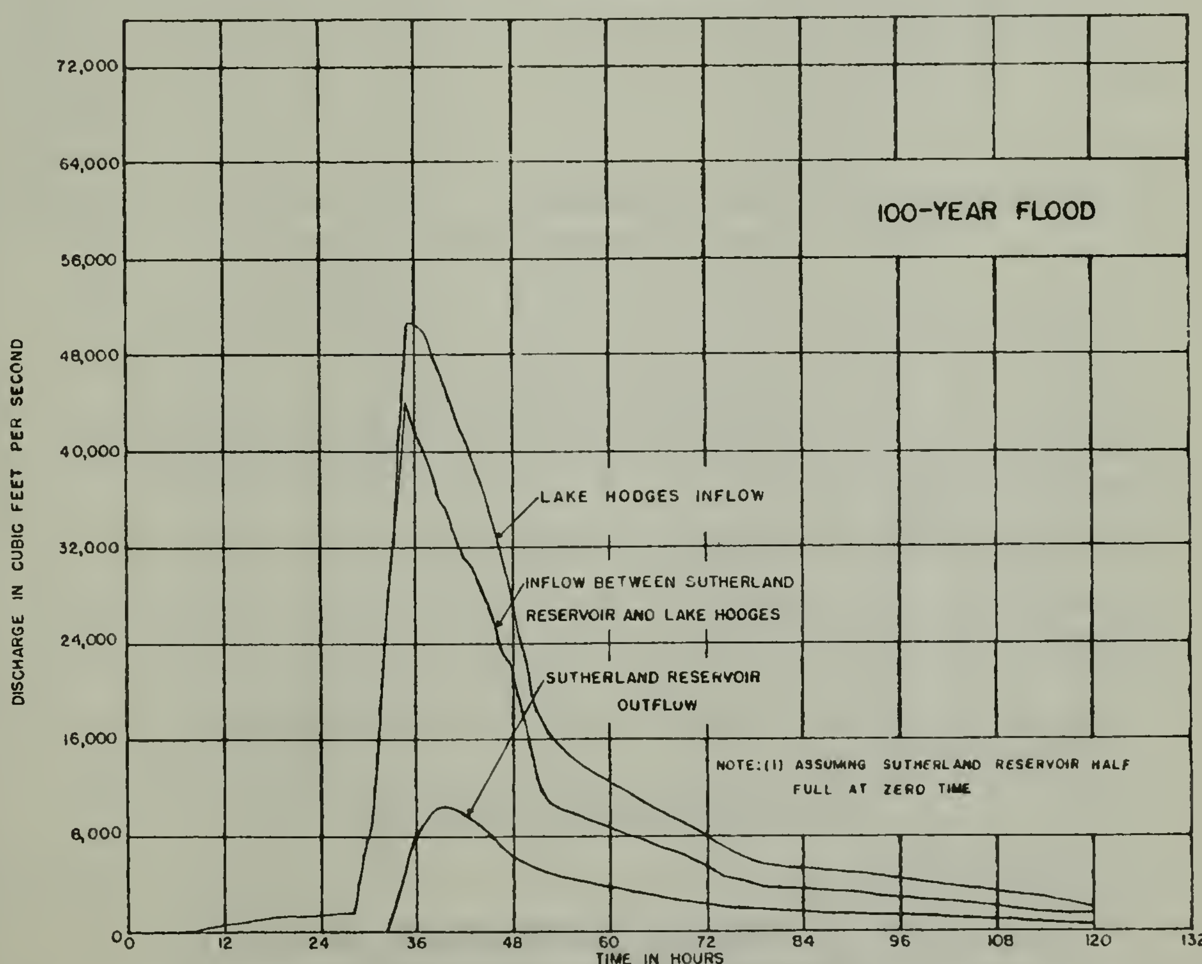
No adjustment of the Lake Hodges inflow hydrographs was necessary for the condition of Sutherland Reservoir being full at the time flood runoff begins. For this condition peak discharges are not reduced significantly by Sutherland Reservoir and it was believed that other approximations in the computed data made this minor adjustment unwarranted.

The spillway discharge and storage capacity curves for Lake Hodges are shown in figure 6. Results of the reservoir routing for the 50- and 100-year floods, for the condition of full reservoirs at both Sutherland and Hodges are given in figure 7, and for the condition of both reservoirs half-full in figure 8. The effect of the reservoirs on the flood peaks is summarized in table 2.

Table 2.--Peak discharges at Lake Hodges

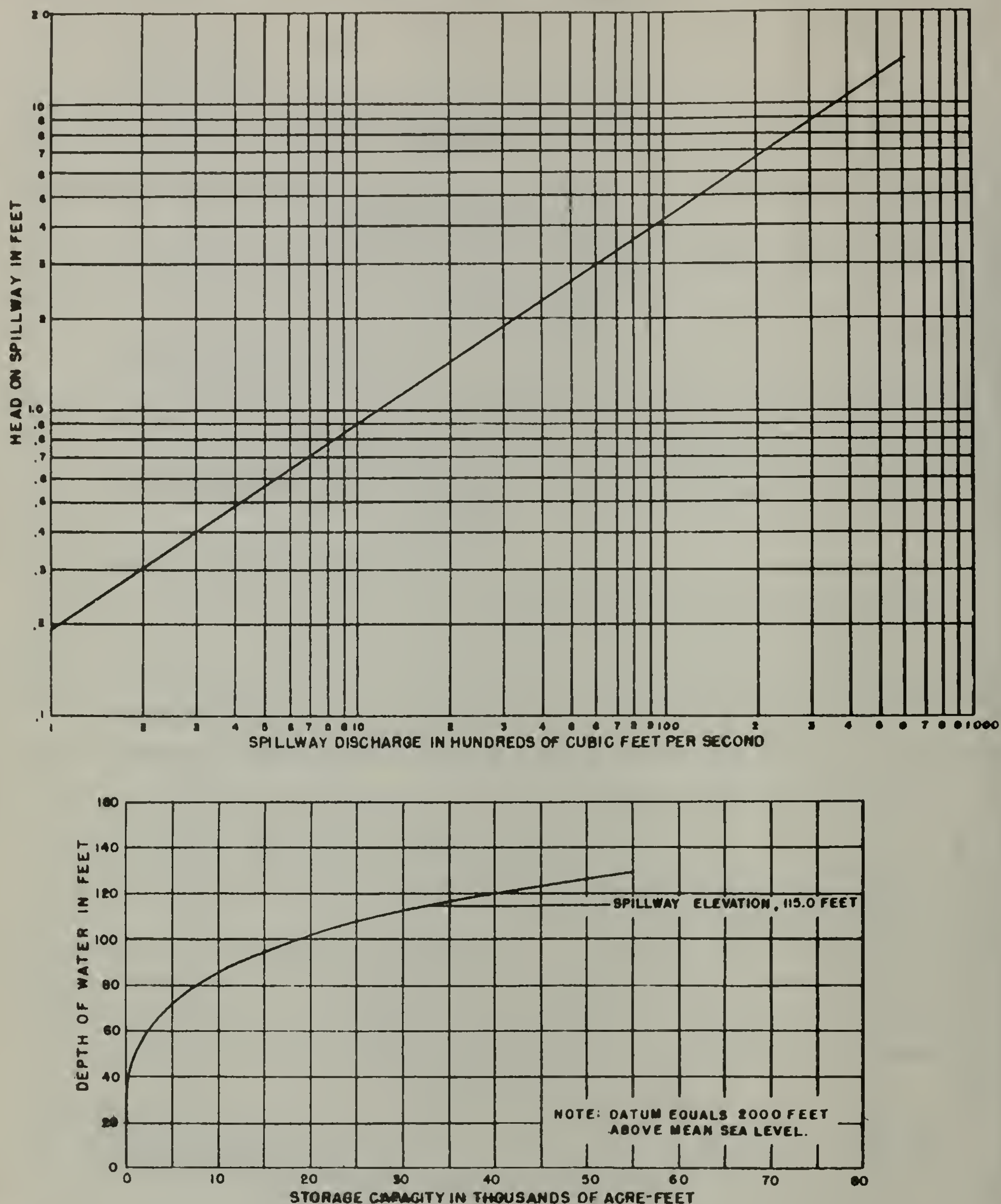
Flood Frequency and Reservoir Condition	Peak Discharge (cubic feet per second)	
	Inflow	Outflow
50-year Flood		
Reservoir full	40,800	32,300
Reservoir half-full	31,000	21,200
100-year Flood		
Reservoir full	58,000	46,600
Reservoir half-full	50,900	38,100



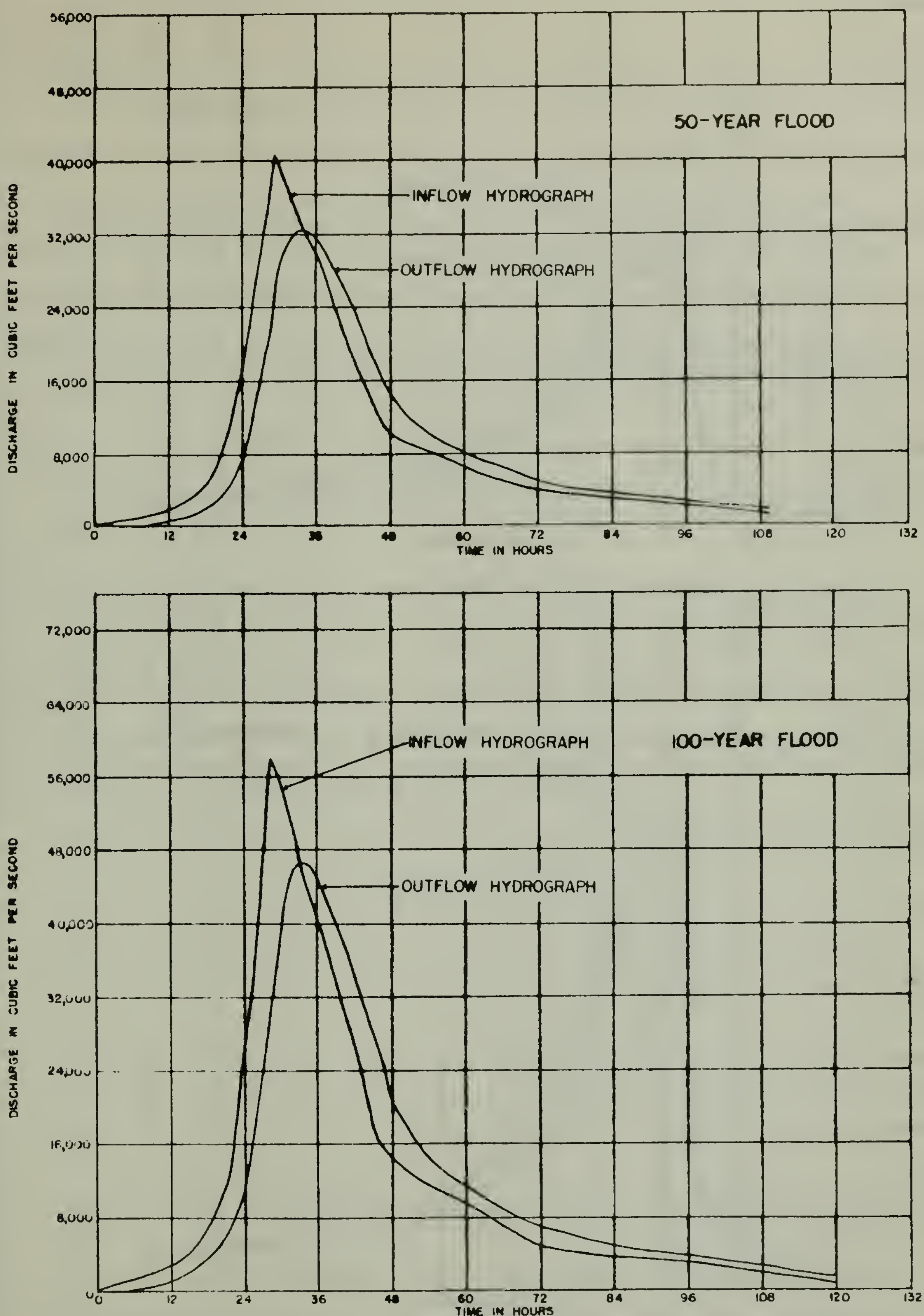


LAKE HODGES INFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS

FIGURE 6

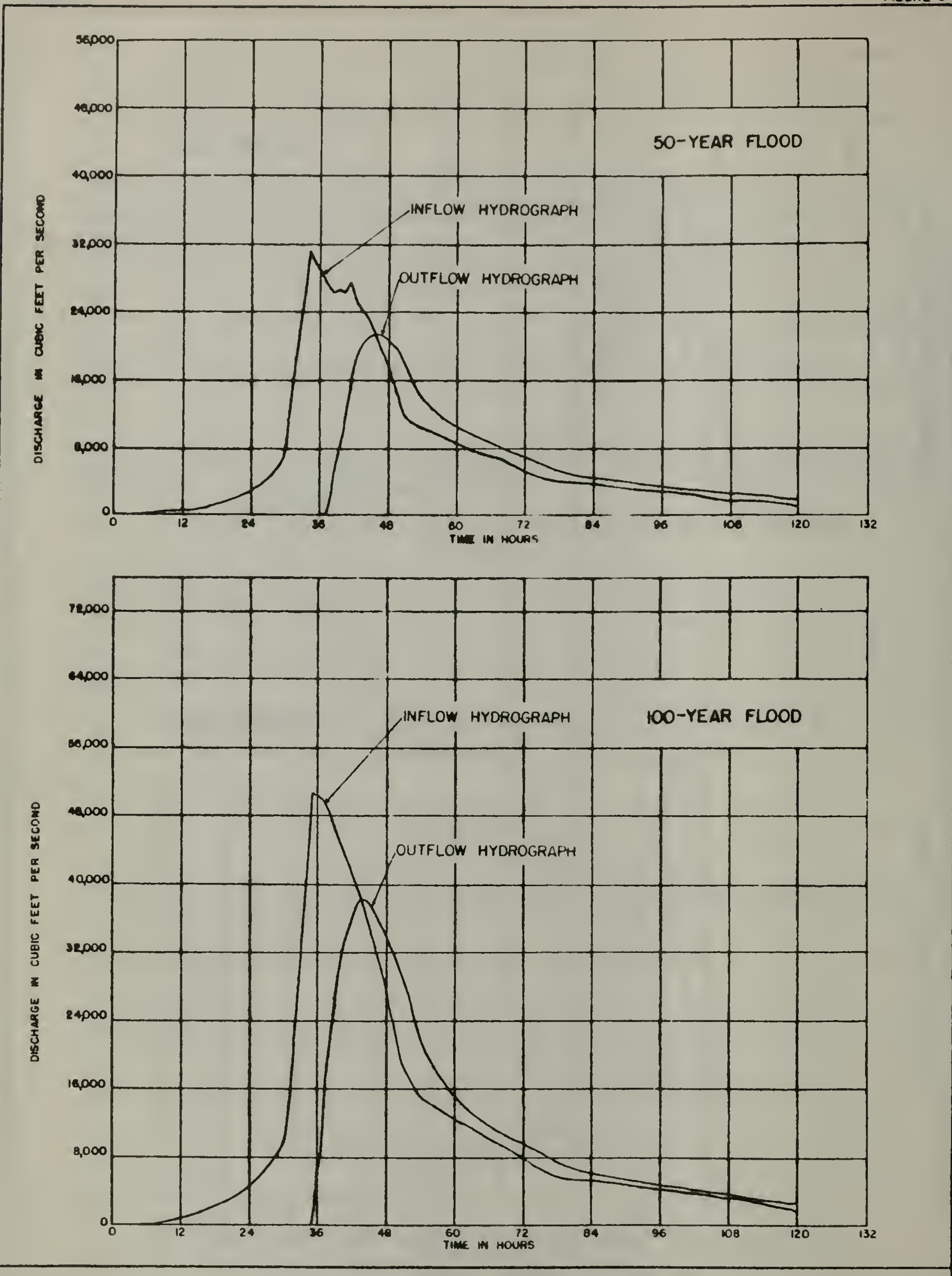


SPILLWAY DISCHARGE AND STORAGE CAPACITY CURVES FOR LAKE HODGES



INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT LAKE HODGES

AT TIME ZERO, RESERVOIR ASSUMED TO BE FULL



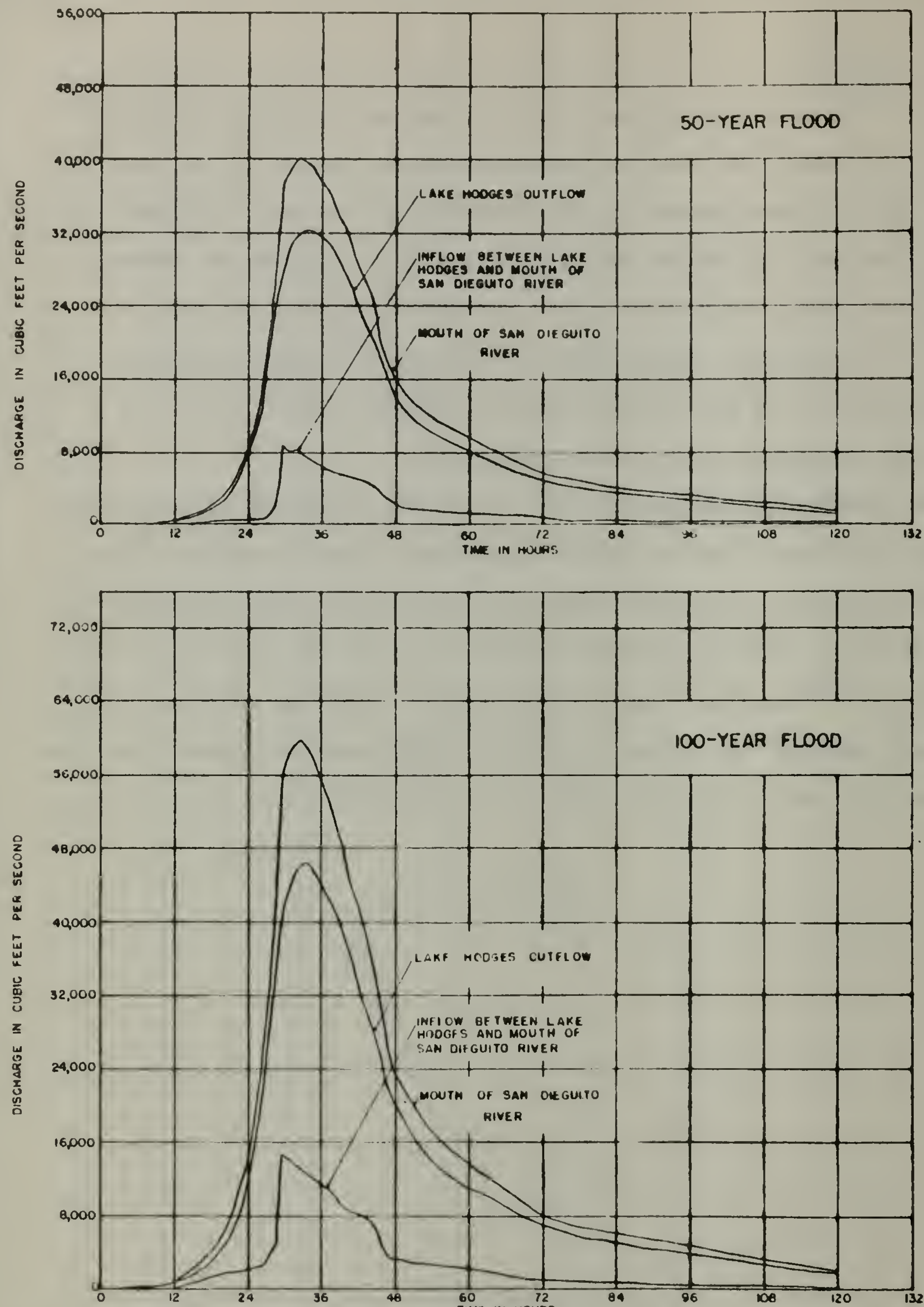
INFLOW AND OUTFLOW HYDROGRAPHS FOR 50-YEAR AND 100-YEAR FLOODS AT LAKE HODGES

AT TIME ZERO, RESERVOIR ASSUMED TO BE HALF FULL

Channel Routing

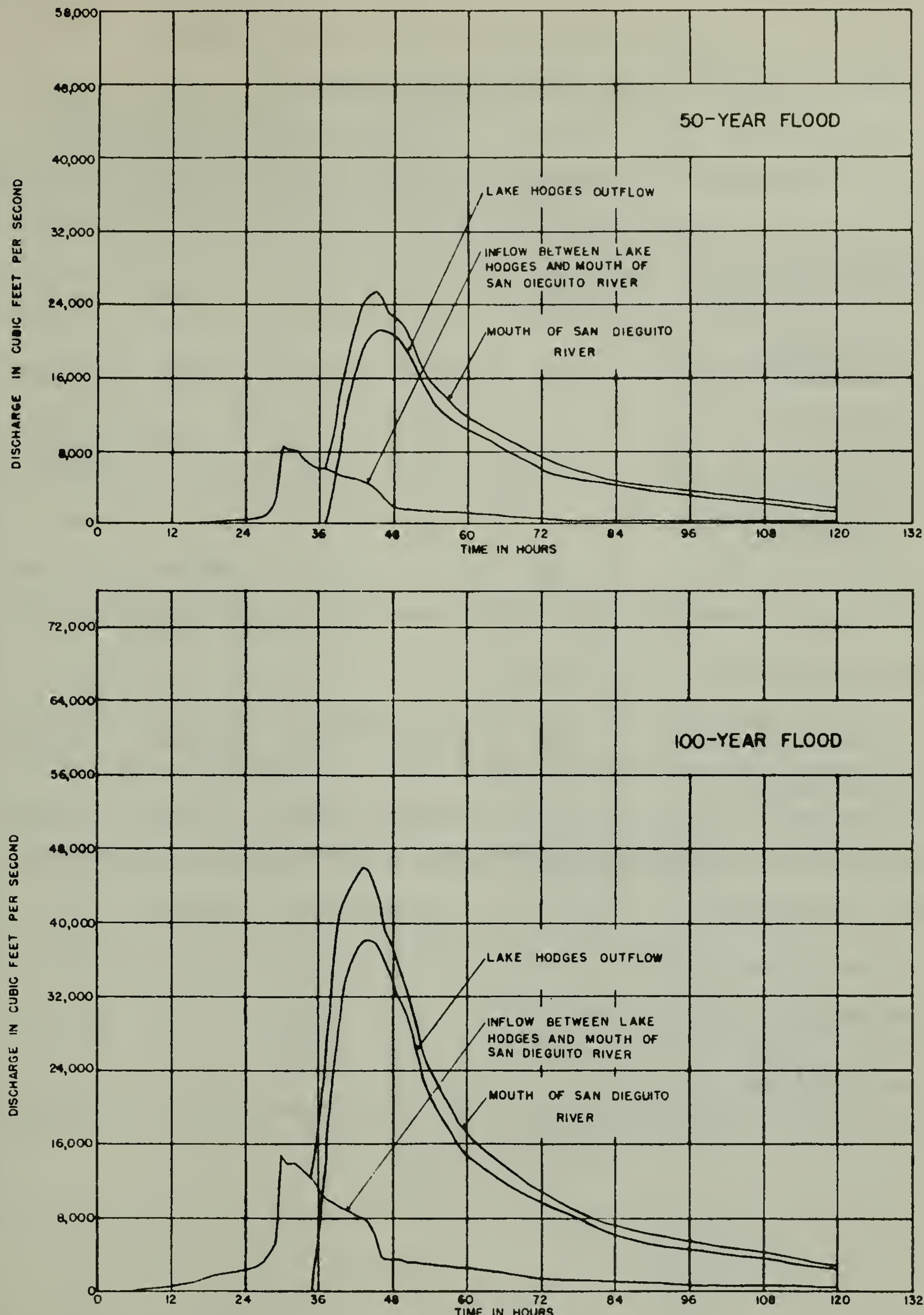
The effect of the reservoirs on peak discharges at selected locations along Santa Ysabel Creek and San Dieguito River was computed by the same method used to determine the inflow to Lake Hodges. The natural inflow between the point in question and the next reservoir upstream was computed and added to the reservoir outflow with allowance being made for time of travel. The results of routing the flood hydrograph between Lake Hodges and the mouth of the San Dieguito River are shown in figure 9 and 10, as a sample of the channel flood-routing technique.

To summarize the procedures used: First, peak discharges were determined at selected points in the San Dieguito River basin from the regional flood-frequency analysis. Next, peak discharges were adjusted where necessary for the attenuation caused by reservoir storage, and last, the computed peak discharges at various points along the channel were tabulated. Fifty and 100-year peak discharges for selected locations, with antecedent storage conditions of reservoirs full and half-full are given in table 3.



ADJUSTED HYDROGRAPH FOR 50-YEAR AND 100-YEAR FLOODS AT MOUTH OF SAN DIEGUITO RIVER

AT TIME ZERO, RESERVOIR ASSUMED TO BE FULL



ADJUSTED HYDROGRAPH FOR 50-YEAR AND 100-YEAR FLOODS AT MOUTH OF SAN DIEGUITO RIVER

AT TIME ZERO, RESERVOIR ASSUMED TO BE HALF FULL

Table 3.--Peak discharges in San Dieguito River Basin

Location	Drainage area	Peak flows, in cubic feet per second, adjusted for reservoir effect			
		50-year flood		100-year flood	
		Reservoir full	Reservoir half-full	Reservoir full	Reservoir half-full
San Dieguito River					
At Del Mar----------	346	40,100	25,300	59,800	46,200
At Hodges Dam (Outflow)----------	303	32,300	21,200	46,600	38,100
At Hodges Dam (Inflow)----------	303	40,800	31,000	58,000	50,900
Below confluence of Santa Ysabel and Santa Maria Creeks------------	225	31,200	20,500	45,500	32,500
Santa Ysabel Creek					
Above Santa Maria Creek-------------	163	27,500	16,000	39,500	26,500
At Sutherland Dam (Outflow)----------	55	10,900	4,000	15,700	10,400
Santa Maria Creek		No Reservoirs in Basin			
At Ramona Gage-------	57.3	15,000		21,400	
At Ramona Airport Road Bridge--------	32.0	10,000		14,500	
Hatfield Creek mouth-------------	16.5	7,400		10,700	

CHANNEL HYDRAULICS AND BACKWATER COMPUTATIONS

Stream Characteristics

Beginning in 1943 and continuing to the present (1963), the San Dieguito River watershed has experienced the most severe drought of record, and streamflow has been well below normal. As a result of long periods of no flow, continued vegetal growth has reduced the streamflow capacity of the main channel. This is not critical in the narrow mountain canyons where floodflows are confined between the canyon walls. However, along the wide coastal plain, a flood occurring now would spread across more of the flood plain than it would have before the reduction in the main-channel carrying capacity. Consequently, great damage threatens agricultural, business, or residential occupany in potential flood areas.

The purpose of this study is to delineate areas that will be inundated by a hypothetical 50-year or 100-year flood. Hypothetical flood boundaries are defined from water-surface profiles that are computed from channel cross sections. Cross sections of the river channel and flood plain were taken from large-scale maps (1 inch equals 200 feet) or obtained by field survey methods at selected points along a reach of stream. These data comprise an essential part of the standard step method of backwater analysis which was used to determine the resultant water-surface profiles for the 50- and 100-year floods.

The basic equation used in computing water-surface profiles is the Manning equation which requires not only a knowledge of the channel geometry but also an estimate of the channel roughness. The Manning equation is

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

where Q is discharge, in cubic feet per second

n is coefficient of roughness

A is area, in square feet

R is hydraulic radius, in feet

S is slope of the energy line, in feet per foot

Roughness Coefficients

The roughness coefficient, "n", used in the Manning discharge equation, is affected primarily by the following factors: bed roughess, vegetation, channel irregularity, channel alinement, scouring and filling, and stage.

For several years a continuing effort has been made by the Geological Survey to widen the range of knowledge with respect to Manning's "n" or roughness coefficient values for open channels. Indirect measurements of discharge are made under favorable conditions, where the discharge is known. The formulas are then used with known discharge values to compute the value of "n". These computed "n" values serve as a guide for selecting the roughness coefficients for similar channels. Stereo-photographs of the channels for which the "n" values have been verified are available for photographic comparison with the channel under study.

All roughness coefficients used in the backwater analysis were selected by engineers of the Geological Survey. Stereo-photographs were taken to implement field reconnaissance notes and to compare with photographs of similar channels with verified "n" values. In the narrow, steep, canyon reaches the 50- and 100-year floods are confined in a channel with a somewhat trapezoidal cross section, having no appreciable flood plain. Roughness coefficients for these reaches are fairly high, ranging from about 0.06 to as high as 0.10 where the brush, trees, and boulders predominate.

For flood stages on the flat, wide valley floors, the main channel is usually a very small part of the river cross section. The "n" values for these reaches range from about 0.03 for the main channel to as high as 0.05 for the wide flood plain with shallow depths. The "n" value for the flood plain usually decreases rather rapidly with increase in depth to a value of about 0.03.

Standard Step Method of Backwater Computation

The standard step method of backwater computation has been used to compute the profiles necessary to determine the extent of flooding by the hypothetical floods. The data necessary for its use are:

1. Discharge for which the profile is desired.
2. A water-surface elevation at the downstream end of the desired reach.
3. The cross-sectional area and hydraulic radius at various points along the channel for all depths of flow within the range expected.
4. The hydraulic roughness of the channel.

The discharges for the 50- and 100-year floods were obtained from the regional flood frequency study.

Starting at the section at the downstream end of the reach, with the known discharge and corresponding water-surface elevation, an estimate is made of the water-surface elevation at the next section upstream. The hydraulic radius and velocity head can then be computed at each section and the Manning equation used to route the flow upstream, thereby obtaining a water-surface elevation at the upstream section. If this computed elevation does not check the elevation that was previously estimated, a new estimate is made of the water-surface elevation and the process repeated until the estimated and computed elevations agree. This procedure is then repeated in the next reach upstream.

Constrictions imposed on a natural river channel and flood plain usually cause some increase in the water-surface elevation upstream. All bridges in the reaches of river under study were investigated for their effects, if any, on the water-surface profiles. Methods outlined in Geological Survey Circular 284 (Kindsvater and others, 1953) were used in the analyses. The water-surface profiles were first computed using the natural channel cross sections and then the effects of bridge constrictions were computed and the profiles adjusted accordingly.

The Geological Survey has developed a program for computing backwater profiles for tranquil, gradually-varied flow, using an electronic computer. The program is set up to compute water-surface profiles for as many as 10 different discharges at one time. Use of the computer greatly expedited the study.

Stage-discharge Relations

San Dieguito River.--The starting point for backwater computations is a downstream site where the stage-discharge relation is known. The stage-discharge relation for the lower reach of the San Dieguito River is complicated by presence of the U.S. Highway 101 bridge, the Atchison, Topeka, and Santa Fe Railroad bridge, the new Interstate Highway 5 bridge, which is under construction at the present time, and the Del Mar racetrack complex. For this reason, backwater computations were begun at the upstream side of the Interstate Highway 5 bridge rather than at the mouth of the river.

The stage-discharge relation at the site of the Highway 5 bridge, was first determined for the unconstricted valley, by the slope-conveyance method, then adjusted for backwater caused by the bridge constriction. The slope-conveyance method makes use of the Manning equation which may be written in the form, $Q = KS^{\frac{1}{2}}$. The conveyance ($K = \frac{1.486}{n} AR^{2/3}$) can be computed from cross-section properties. The energy slope S, is assumed to be parallel to the channel slope for this particular computation, and can be measured in the field or from topographic maps.

The effect of the bridge constriction on this computed stage-discharge relation was determined and the adjusted stages were used in the standard step method to determine the water-surface profile from the Interstate Highway 5 bridge upstream to Hodges Dam.

The stage-discharge relation for Lake Hodges spillway was computed by use of the weir formula:

$$Q = CLH^{3/2}$$

where

Q is discharge, in cubic feet per second

C is an empirical coefficient

L is measured length of weir, in feet

H is measured head, in feet

This relation provided the initial water-surface elevations, used in routing the selected discharges upstream from the lake.

Santa Maria Creek.--The starting point for backwater routing computations on Santa Maria Creek was the Geological Survey gage near Ramona, where the stage-discharge relation is known. This relation has been defined by current-meter and slope-area measurements for the low to medium stages. Slope-conveyance computations were used in extending this relation above the range defined by the measurements.

AREAS OF POTENTIAL INUNDATION

Water-Surface Profiles

The stage-discharge relations were used in conjunction with hydraulic properties of the channel at cross sections located at strategic points along the San Dieguito River system to obtain water-surface profiles. Generally, the cross sections were located about 2,000 feet apart but the distance varied depending on the uniformity of hydraulic properties of the particular reach under consideration. The computed water-surface profiles were adjusted for the effects of bridge constrictions where necessary.

Because of the complex geometry of the San Dieguito River from its mouth to Interstate Highway 5 bridge, it was not possible to apply the standard step method of backwater computations in this reach of channel. A following section entitled "Special Conditions below Interstate Highway 5 Crossing" contains a qualitative discussion of methods used to define the extent of inundation in this reach.

Extent of Flooding

The extent of flooding in the river basin by the 50- and 100-year peak flows is shown on strip maps which were prepared from Geological Survey 7½ minute topographic quadrangles. Maps showing the San Dieguito River from its mouth to the confluence of Santa Ysabel and Santa Maria Creeks are shown as Plates 4-A1, 4-B1, and 4-C1 for the conditions of full reservoirs at beginning of storm runoff. Plates 4-A2, 4-B2, and 4-C2 show the same reaches of stream for the condition of half-full reservoirs at beginning of storm runoff. The letter designation shown in the plate numbering scheme refers to the strip map locations shown on the Key Map on each plate and also on plate 3.

Plates 4-D1 and 4-D2 reflect the areas of potential inundation for the two reservoir conditions, for Santa Ysabel Creek from its mouth to the gaging station above San Pasqual Valley.

Plate 4-E1 depicts the extent of potential flooding for the 50- and 100-year peaks from the gaging station near Ramona (head of Bandy Canyon) to the vicinity of State Highway No. 67 crossing on Hatfield Creek, the major tributary, just northeast of the city of Ramona.

Flood boundaries were determined by use of the computed water-surface profiles and selected river cross sections. The edge of water at each end of a particular cross section occurs where ground and water elevations coincide. Flood boundary lines based on these points, were drawn between cross sections by interpolation between contours and field checked. A grid of elevations to the nearest foot or half a foot appears on the large-scale (1 inch equals 200 feet) maps to facilitate plotting of flood boundaries between cross sections.

Special Conditions Downstream from Interstate Highway 5 Crossing

In the 7,000-foot reach of the San Dieguito River between its mouth and the new Interstate Highway 5 crossing a complex hydraulic situation exists, which is not adapted to the standard step method of computing water surface profiles. The Grand Avenue bridge, Del Mar Racetrack complex, Atchison, Topeka, and Santa Fe Railroad bridge, U.S. Highway 101 bridge and the sandbar at the mouth of the river are all located in this reach of river and serve to complicate any hydraulic analysis of flood flow.

Mouth of San Dieguito River.--The river channel at the Pacific Ocean is blocked by a sand bar deposited to a height of about 8 or 9 feet above mean sea level by tidal action. Scour occurs when the sand bar is overtopped by floodwaters but a considerable area of flood plain is usually inundated before this action occurs.

Flood boundaries between the ocean and the Highway 101 bridge shown on Plates 4-A1 and 4-A2, reflect this condition. It is assumed that the sand bar will be washed out rather rapidly when it is overtopped by floodwaters. For this reason it is probable that the elevation of the floodwaters will not rise much above the elevation of the top of the sand bar at the time the flood occurs. The effect of the ocean tides on the water-surface elevation after the floodwaters have overtopped and scoured out the sand bar must be considered. Owing to the fact that the half-tide level (average of mean low and mean high tides) is about three feet above mean sea level (from U.S.C. & G.S. data for San Diego area tide gages) at the mouth of the San Dieguito River, it is improbable that the elevation of the river floodwaters would exceed 8 or 9 feet, the present elevation of the sand bar.

The highest tide recorded along the southern California coast in recent years is about 8 feet. If a tide of this magnitude were to occur simultaneously with a peak discharge of 50- or 100-year recurrence interval, the floodwaters in the lower reach of river could possibly rise above the 10-foot elevation estimated for purposes of delineating the inundated areas shown on plates 4-A1 and 4-A2. A combination of high tide and strong wind, with resultant wave action could also cause the floodwaters to inundate more area than that indicated on the map.

U.S. Highway 101 Bridge and Road Overflow.--The effective waterway area of the U.S. Highway 101 bridge opening has been reduced considerably by sand deposits. Floodwaters usually produce a certain amount of scour under the bridge. An estimate of the magnitude of this scour was made before attempting to determine the effect of the bridge on the floodwaters. Methods outlined in Geological Survey Circular 284 were used to determine the water-surface elevation at the upstream side of the bridge for selected discharges. The results show that for the 100-year flood the upstream elevation would be higher than the roadway south of the bridge and that a section of roadway several hundred feet long would be inundated. Further computations indicate that the 50-year flood peak would be contained by the present river channel with only slight possibility of the roadway being flooded.

U.S. Highway 101 Bridge to new Interstate Highway 5.--Presently situated on the river flood plain between U.S. Highway 101 and Interstate Highway 5 are the Atchison, Topeka and Santa Fe Railroad bridge, the Del Mar racetrack complex, the Southern California Exposition Fairgrounds buildings, and the Grand Avenue Bridge. Consequently, it was impossible to determine reliable water-surface profiles in this reach by use of the electronic computer program. Water-surface elevations were computed at points just upstream from U.S. Highway 101 bridge and just downstream from the new Interstate Highway 5 crossing, and water-surface elevations shown on the maps for the intervening reach were obtained by straight-line interpolation between the points.

Grand Avenue bridge and the railroad bridge have been damaged by at least two previous floods and may be damaged again in the future. Plate 1 shows the condition of the Atchison, Topeka and Santa Fe Railroad bridge during the flood of February 1927.

To summarize briefly, the areas of potential inundation on the San Dieguito River flood plain in the vicinity of Del Mar, shown by maps included in this report, reflect the considered judgment of the authors of the complex hydraulic situation that exists in this reach of the river.

HISTORICAL FLOODS IN SOUTHERN CALIFORNIA

This report would not be complete without some mention of notable floods that occurred in the past in the San Dieguito River basin. Since 1770 flood runoff from the Coast Ranges has been observed and records of floods are found in a wide variety of publications. Early references to floods are found in diaries of the Spanish Mission Fathers. Official weather observations in southern California were begun at San Diego in 1851. The first known estimates of flood discharges were made for a flood in 1889 on the Los Angeles River.

Available data indicate that major floods in the San Dieguito River Basin occurred in 1825, 1833, 1862, 1867, 1884, 1891, 1916, and 1927, that the largest and second largest floods of recent times occurred in 1916 and 1927, respectively. The 1916 flood is considered the flood of record for the San Dieguito River.

An autobiography entitled "Memoirs of Edward Fletcher" contains the following eye-witness account of the 1916 flood:

> "The San Dieguito River north of Del Mar was a half-mile wide and there was four feet of water -- a raging torrent -- covering the present race track site."

Mr. Fletcher also states "that there was 3 feet of water across the entire valley opposite Rancho Santa Fe".

Plate 1 shows the approximate area described above but depicts the flood of 1927 which occurred 11 years later.

Plate 2 shows damage caused by the 1927 flood at points along Santa Ysabel Creek in San Pasqual Valley. This area is presently in cultivation.

The historical information and the pictures included in this report result from a limited search made during the field investigations for this project.

SUMMARY

The flood hazard along the San Dieguito River, one of the five principal streams in San Diego County, has been investigated using peak discharges for hypothetical floods having 50- and 100-year recurrence intervals. These peak discharges were determined by a regional flood-frequency analysis of streamflow records in and adjacent to the project area. A composite dimensionless hydrograph, based on available recorded flood hydrographs for all major rivers in the area, was developed and reservoir flood routing techniques utilized to determine the amount of reservoir attenuation of the hypothetical peak discharges. Two conditions of reservoir content was considered (1) all reservoirs in the basin full at beginning of runoff, and (2) all reservoirs in the basin half full at beginning of runoff.

The areas of the San Dieguito River flood plain that will be inundated by floods of a 50- or 100-year magnitude and frequency are delineated on the maps included with this report. To define these areas it was first necessary to obtain cross-sections and channel roughness coefficients for many points. These data were processed by the standard step method of backwater analysis to compute the water-surface profiles for the 50- and 100-year floods. The areas of potential inundation were delineated from these water-surface profiles for the selected floods.

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Mouth of San Dieguito River at Del Mar, Flood of Feb. 1927

San Dieguito River—View across valley from Rancho Santa Fe to Fairbanks Ranch—River about 2 miles wide—Flood of Feb. 1927

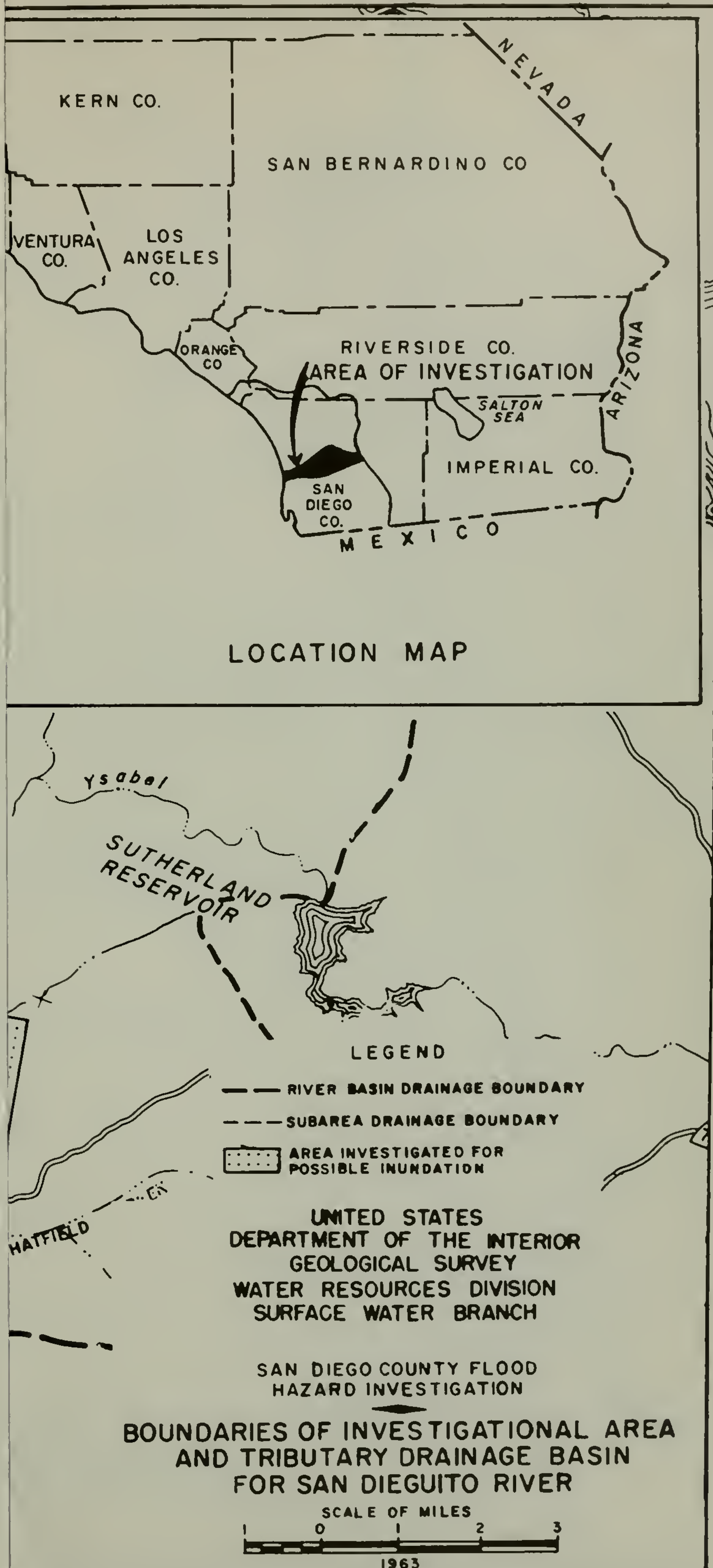
Both pictures from:
HISTORICAL COLLECTION
TITLE INSURANCE and TRUST COMPANY
UNION TITLE OFFICE
SAN DIEGO, CALIFORNIA

GPO 966548

Santa Ysabel Creek in San Pasqual Valley

Santa Ysabel Creek at San Pasqual, Calif.

GPO 966548


NEVADA
KERN CO.
SAN BERNARDINO CO
VENTURA CO.
LOS ANGELES CO.
ORANGE CO
RIVERSIDE CO.
AREA OF INVESTIGATION
ARIZONA
SALTON SEA
IMPERIAL CO.
SAN DIEGO CO.
MEXICO
LOCATION MAP
Ysabel
SUTHERLAND RESERVOIR
HATFIELD
LEGEND
RIVER BASIN DRAINAGE BOUNDARY
SUBAREA DRAINAGE BOUNDARY
AREA INVESTIGATED FOR POSSIBLE INUNDATION
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION
BOUNDARIES OF INVESTIGATIONAL AREA AND TRIBUTARY DRAINAGE BASIN FOR SAN DIEGUITO RIVER
SCALE OF MILES
1 0 1 2 3
1963


LOCATION MAP
KERN CO.
SAN BERNARDINO CO
NEVADA
VENTURA CO.
LOS ANGELES CO
ORANGE CO
RIVERSIDE CO.
AREA OF INVESTIGATION
SALTON SEA
ARIZONA
IMPERIAL CO.
SAN DIEGO CO.
MEXICO
PACIFIC OCEAN
ENCINITAS
BATIQUITOS LAGOON
SAN ELIJO LAGOON
DEL MAR
SAN MARCOS
ESCONDIDO
LAKE WOHLFORD
DEL DIOS
LAKE HODGES
RANCHO SANTA FE
RAMONA
POWAY
MIRAMAR
SUTHERLAND RESERVOIR
SAN DIEGUITO RIVER
A
B
C
D
E
LEGEND
RIVER BASIN DRAINAGE BOUNDARY
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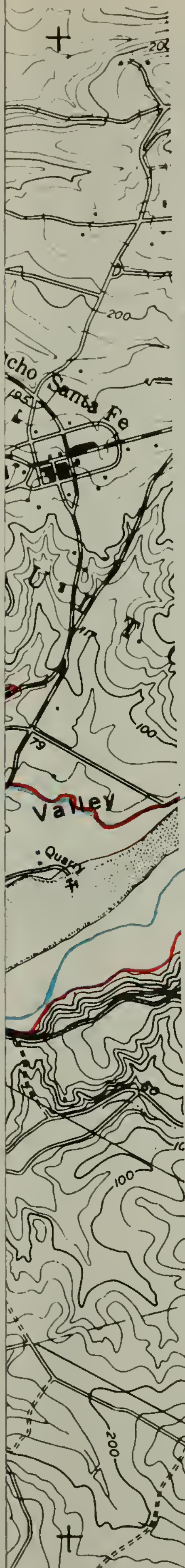
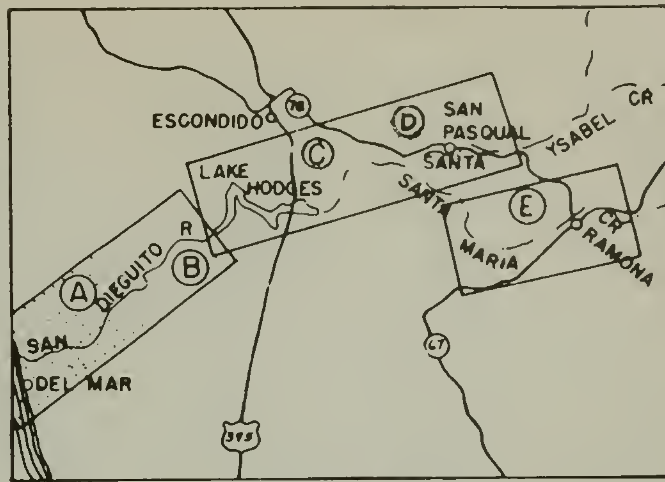
SURFACE WATER BRANCH
SAN DIEGO COUNTY FLOOD
HAZARD INVESTIGATION
BOUNDARIES OF INVESTIGATIONAL AREA
AND TRIBUTARY DRAINAGE BASIN
FOR SAN DIEGUITO RIVER
SCALE OF MILES
1 0 1 2 3
1963





KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

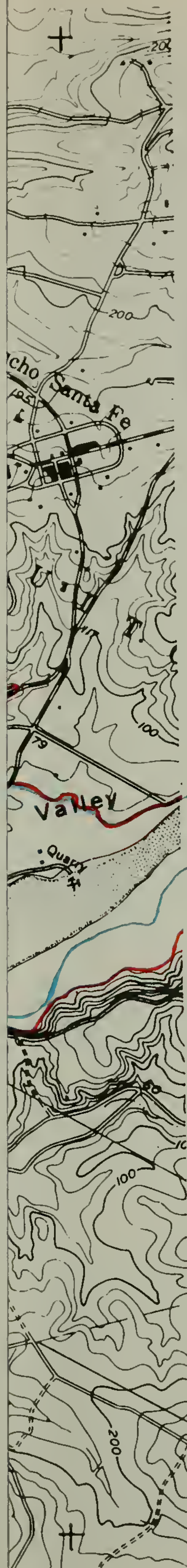
INUNDATED AREA FOR 50-YEAR FLOOD

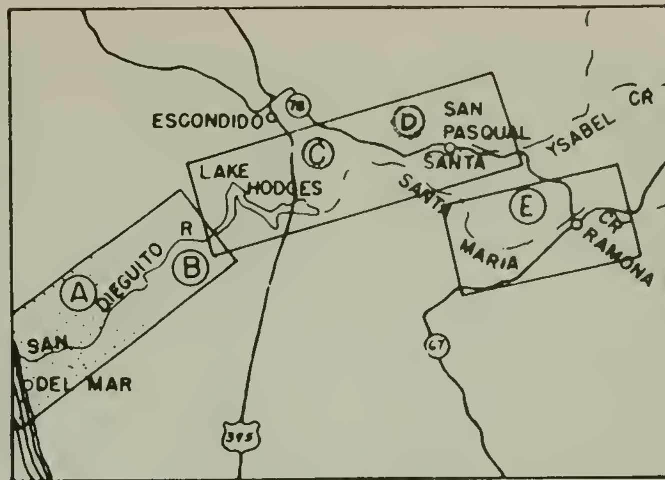
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000





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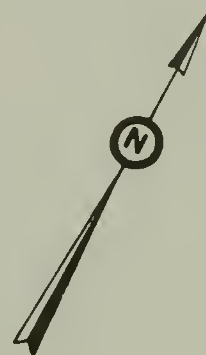


EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

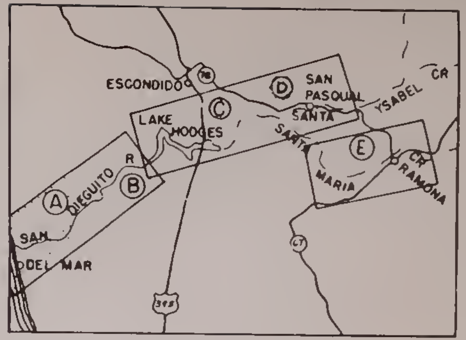
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET

1000 0 1000 2000



KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

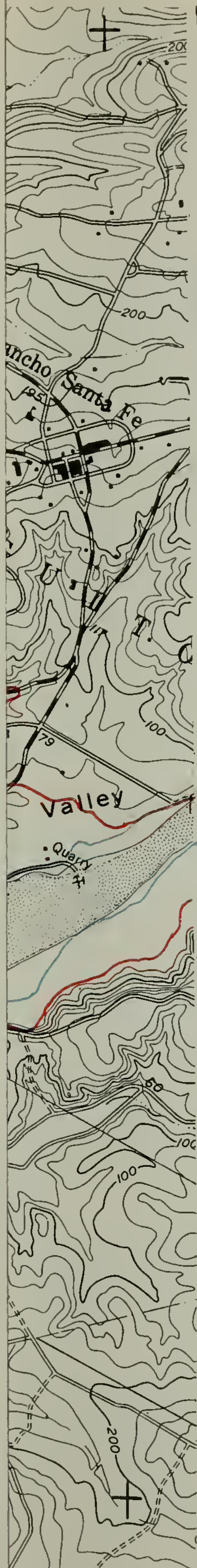
INUNDATED AREA FOR 50-YEAR FLOOD

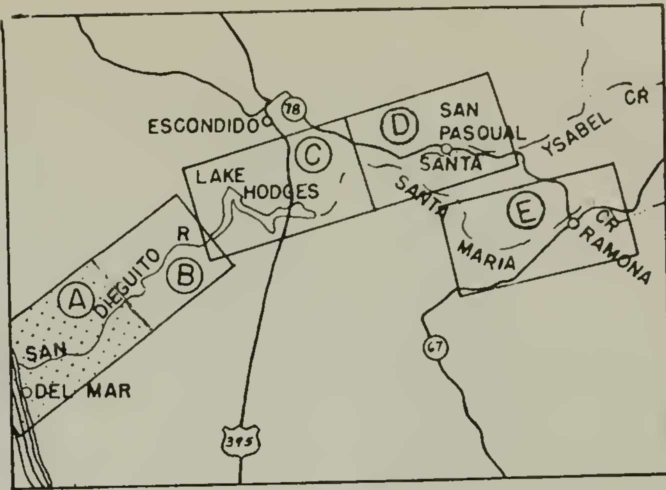
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000





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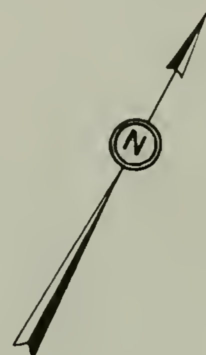


EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

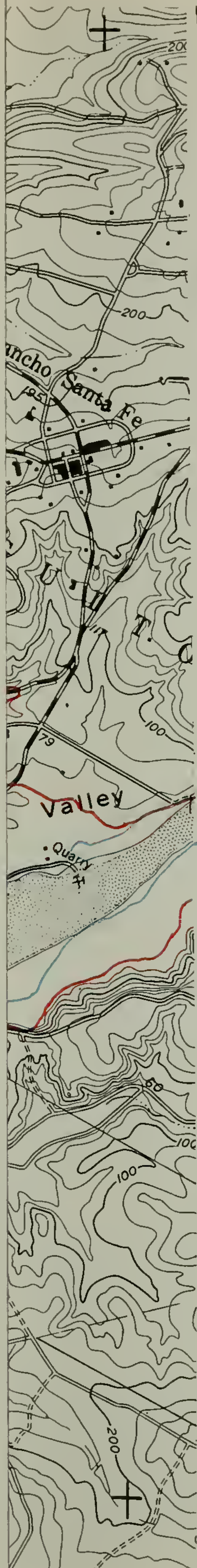
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

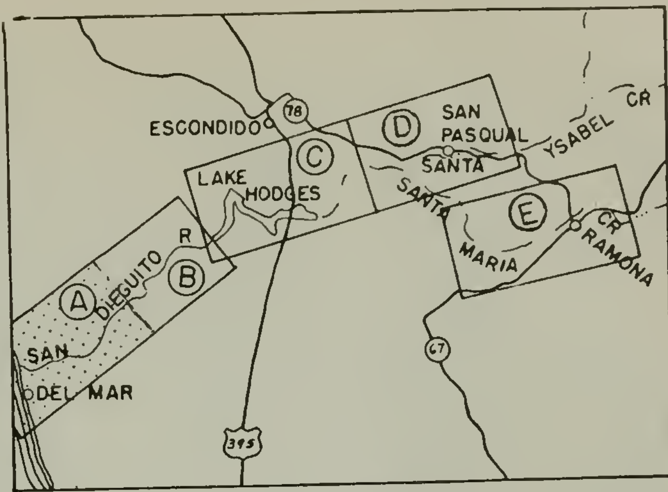
SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL
INITIALLY

SCALE OF FEET

1000 0 1000 2000





KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

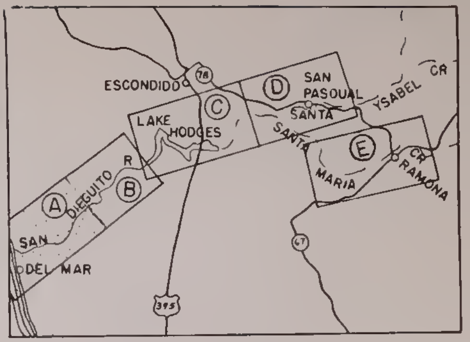
INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL
INITIALLY

SCALE OF FEET
1000 0 1000 2000



KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

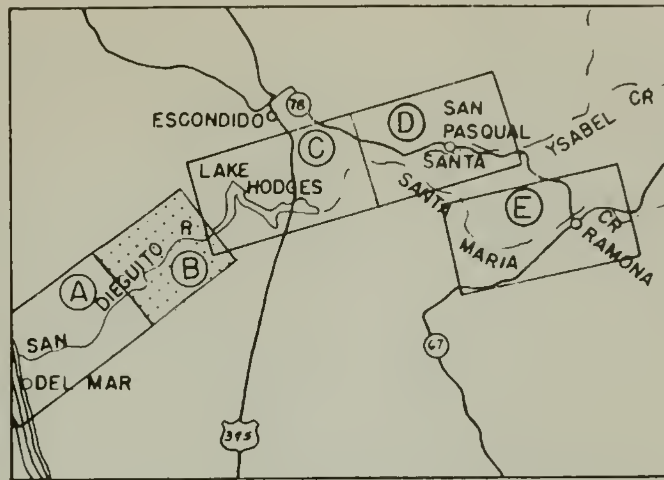
INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

**SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL
INITIALLY**

SCALE OF FEET
1000 0 1000 2000



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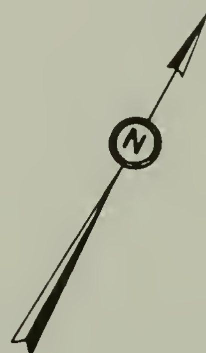


EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

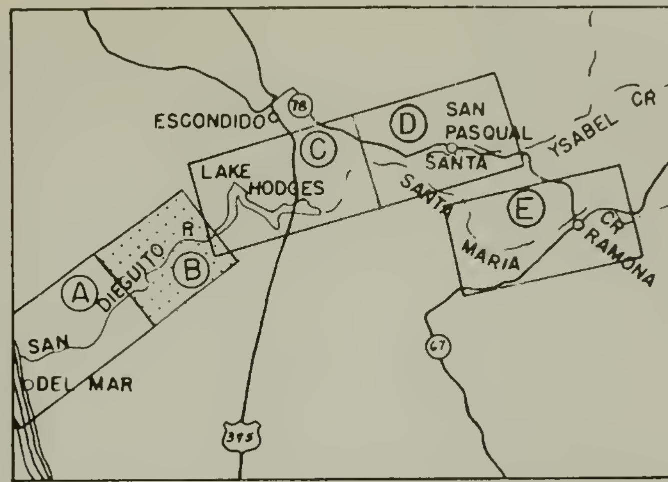
INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

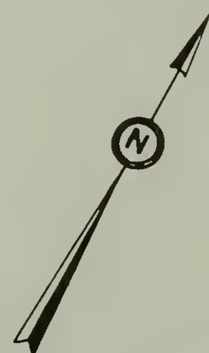
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000



KEY MAP



EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

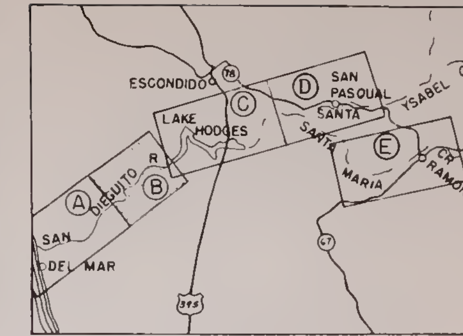
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET

1000 0 1000 2000



KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

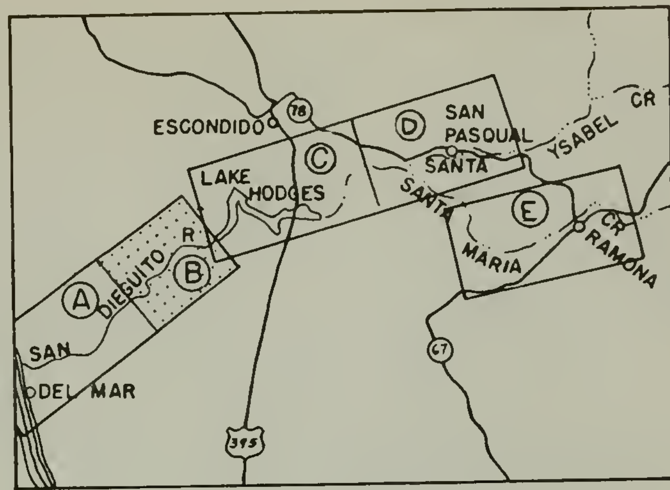
INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000



KEY MAP

EXPLANATION

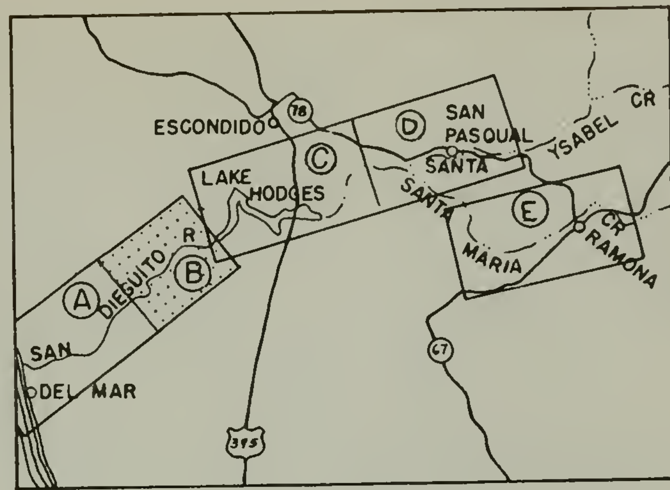
INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN DIEGUITO RIVER AREAS OF POTENTIAL INUNDATION WITH RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000



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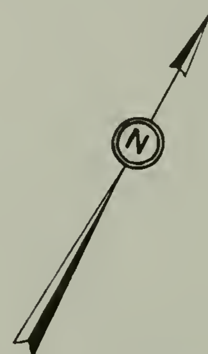


EXPLANATION

INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

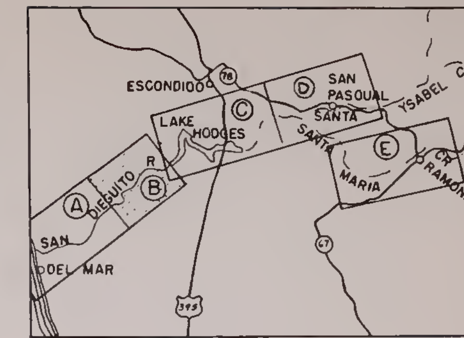
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN DIEGUITO RIVER AREAS OF POTENTIAL INUNDATION WITH RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET

1000 0 1000 2000



KEY MAP

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EXPLANATION

INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN DIEGUITO RIVER AREAS OF POTENTIAL INUNDATION WITH RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET

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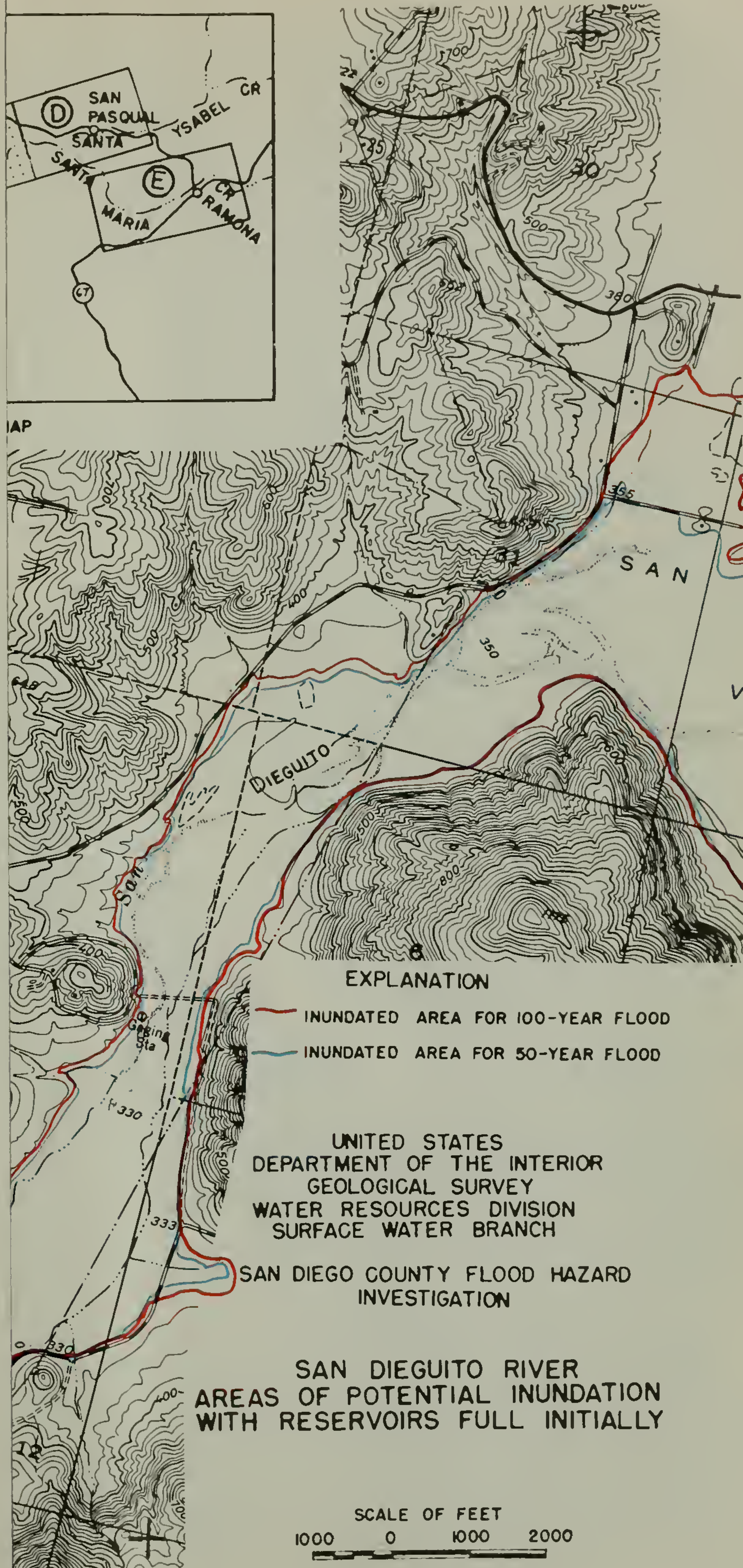

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
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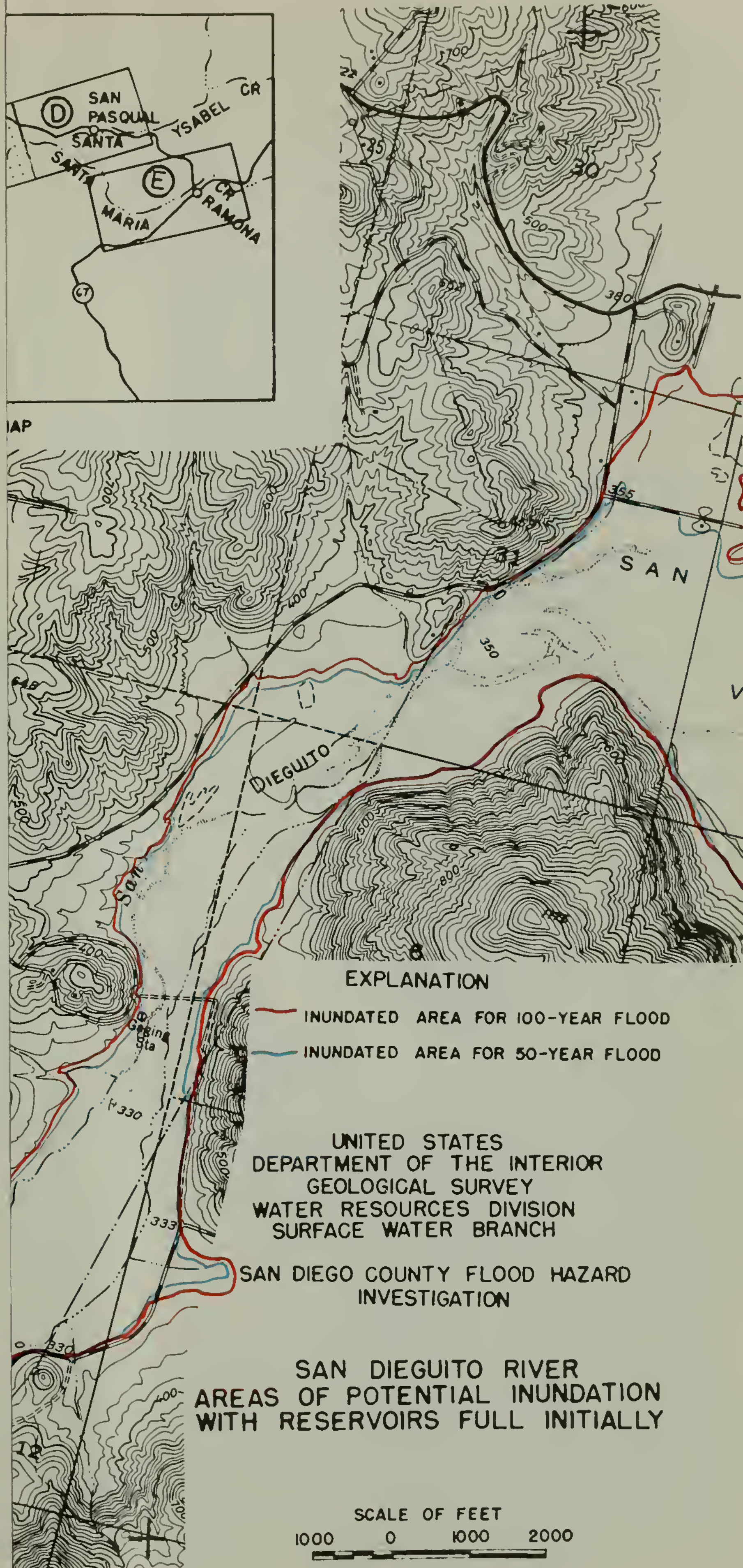
SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000



EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
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INVESTIGATION

SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET

1000 0 1000 2000

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
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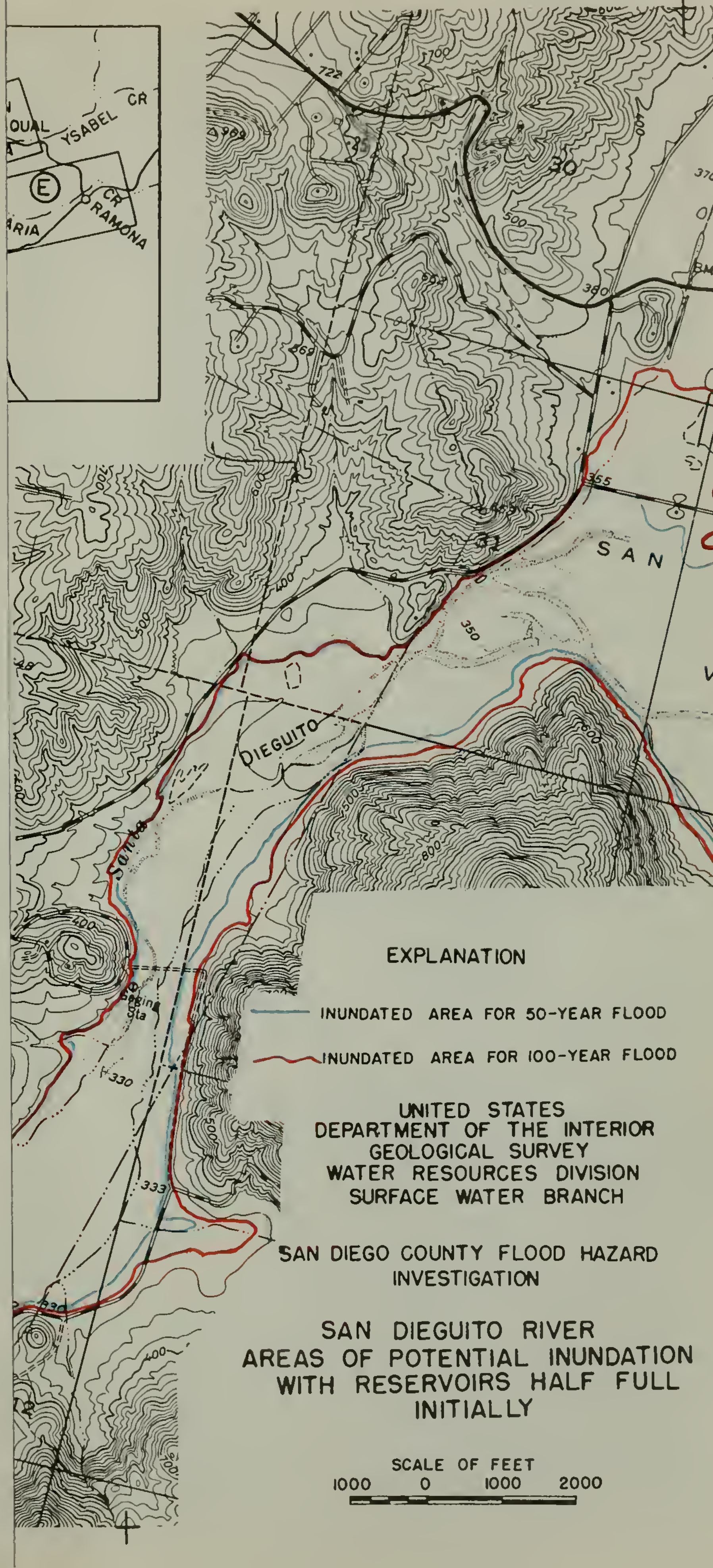
SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000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QUAIL
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DIEGUITO
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EXPLANATION
INUNDATED AREA FOR 50-YEAR FLOOD
INUNDATED AREA FOR 100-YEAR FLOOD
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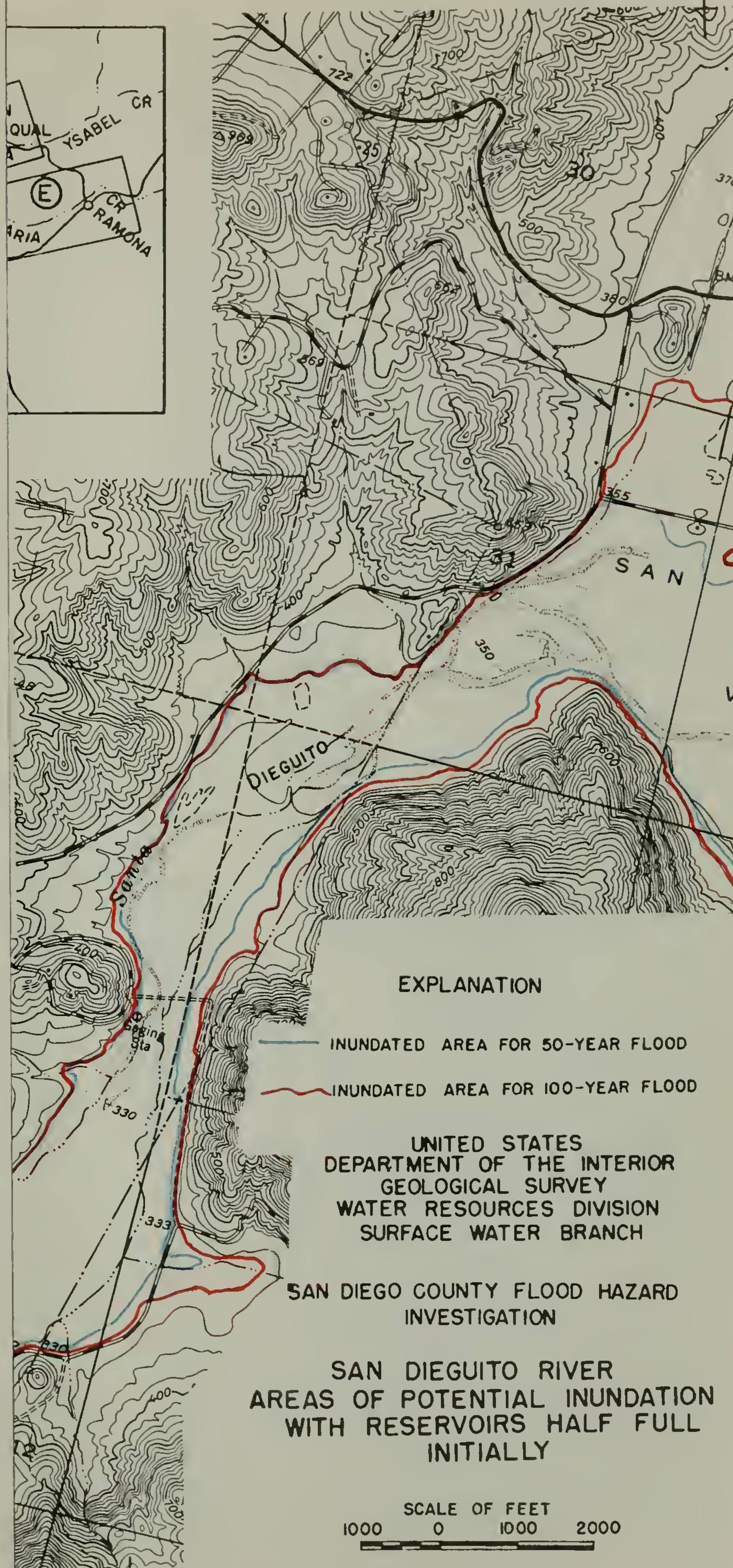
INVESTIGATION
SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL
INITIALLY
SCALE OF FEET
1000 0 1000 2000



EXPLANATION

INUNDATED AREA FOR 50-YEAR FLOOD

INUNDATED AREA FOR 100-YEAR FLOOD

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SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL
INITIALLY

SCALE OF FEET
1000 0 1000 2000

PLATE 4-C2


KEY MAP
ESCONDIDO
SAN PASQUAL
YSABEL CR
LAKE HODGES
SANTA
SANTA MARIA
RAMONA
DIEGUITO R
SAN
DEL MAR
Del Dios
LAKE HODGES
Spillway 314
Lake Hodges
S A N B E R N A R D
SAN DIEGUITO
Bernardo Mtn
Battle Mtn
Dam 396
Dam 388
BM 360
BM 328
BM 320
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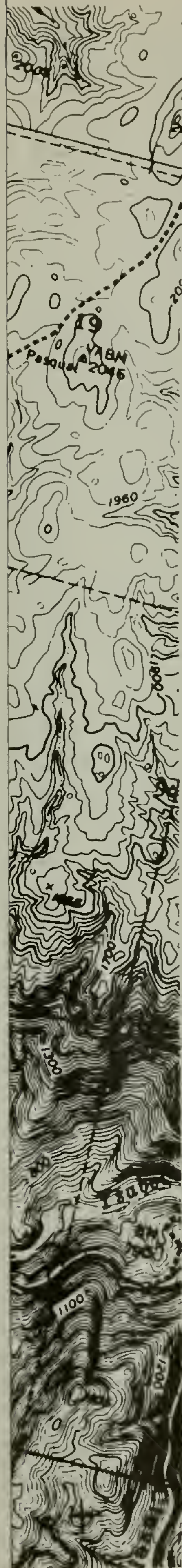
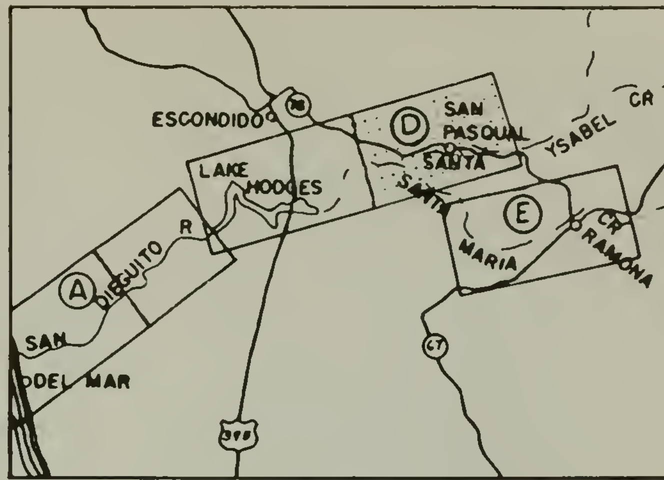
SAN DIEGUITO RIVER
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL
INITIALLY
SCALE OF FEET
1000 0 1000 2000





KEY MAP

N

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
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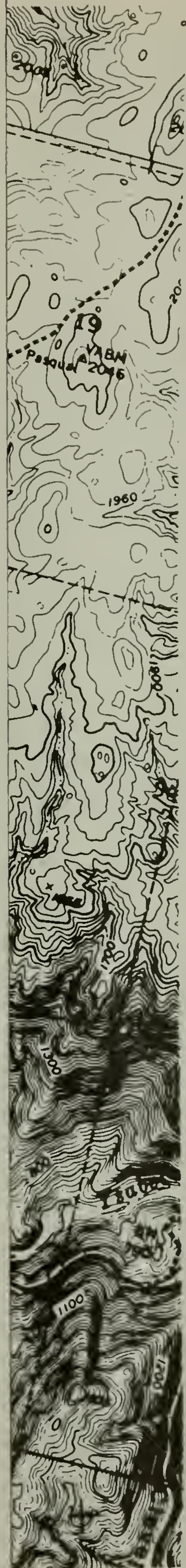
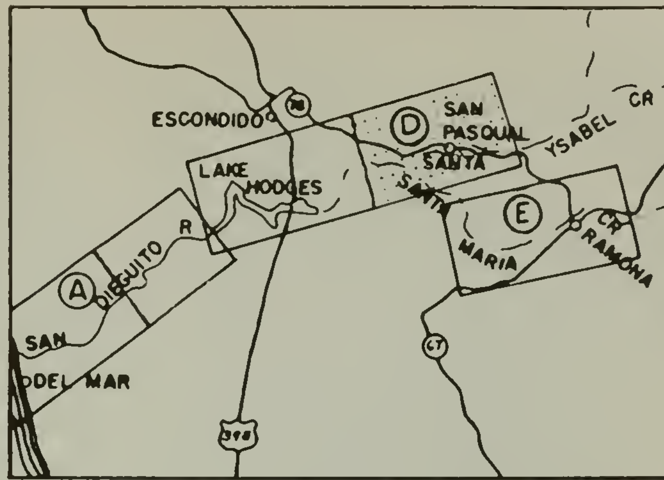
SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SANTA YSABEL CREEK
AREAS OF POTENTIAL INUNDATION WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000





KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
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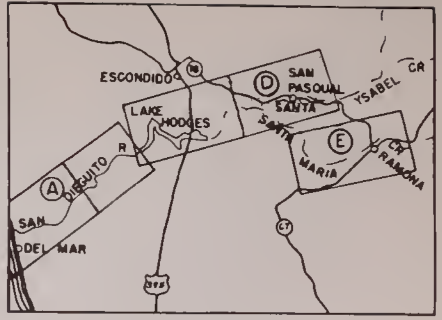
INVESTIGATION

SANTA YSABEL CREEK
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000



KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
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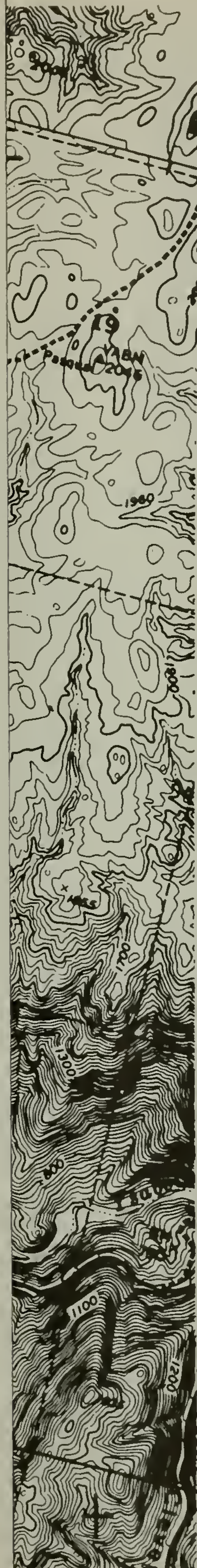
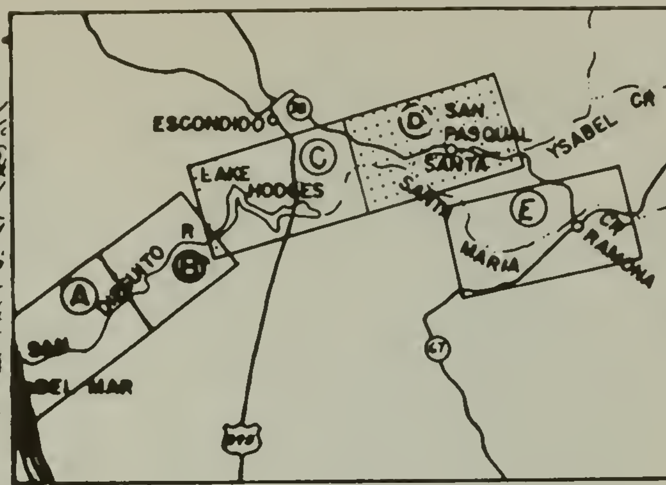
SANTA YSABEL CREEK
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000





KEY MAP

EXPLANATION

INUNDATED AREA FOR 50-YEAR FLOOD

INUNDATED AREA FOR 100-YEAR FLOOD

UNITED STATES
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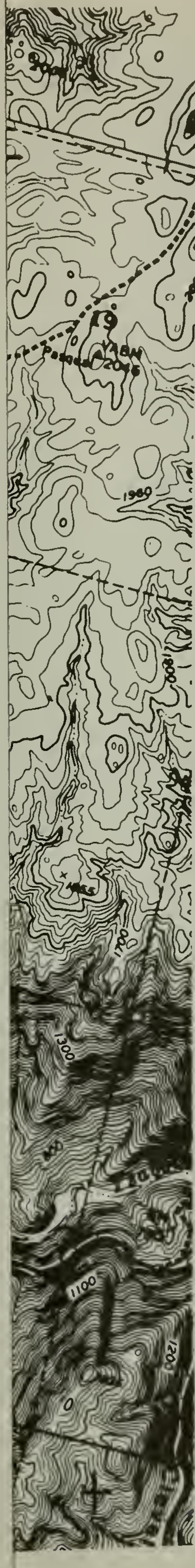
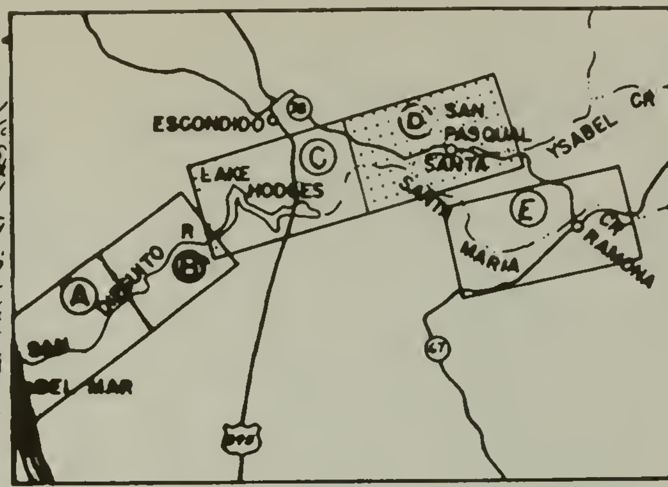
SANTA YSABEL CREEK
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL
INITIALLY

SCALE OF FEET
1000 0 1000 2000





KEY MAP

N

EXPLANATION

INUNDATED AREA FOR 50-YEAR FLOOD

INUNDATED AREA FOR 100-YEAR FLOOD

UNITED STATES
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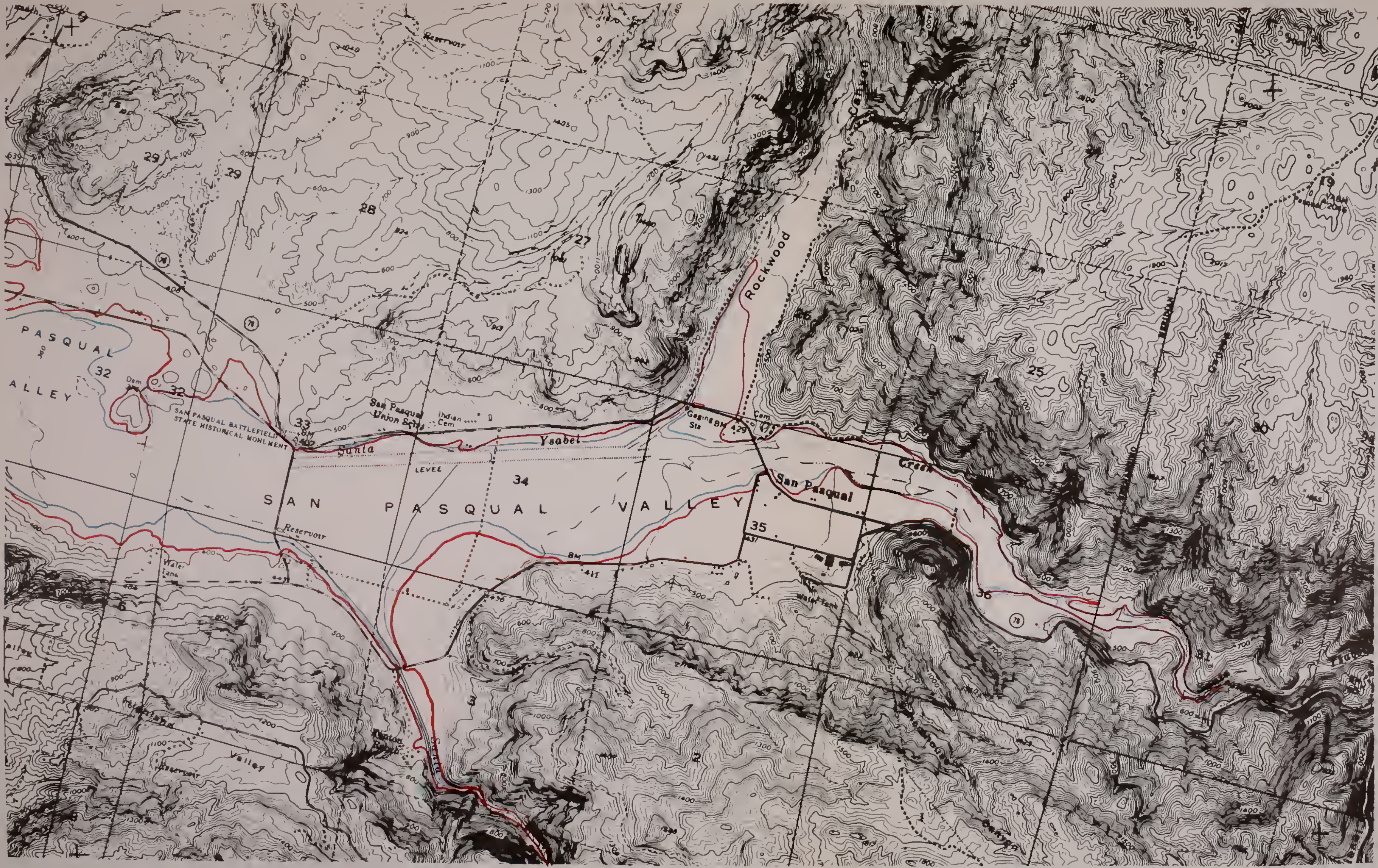
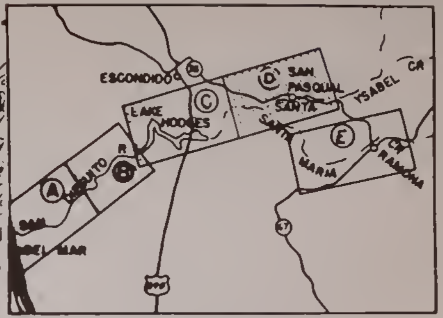
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL
INITIALLY

SCALE OF FEET
1000 0 1000 2000





KEY MAP

EXPLANATION

INUNDATED AREA FOR 50-YEAR FLOOD

INUNDATED AREA FOR 100-YEAR FLOOD

UNITED STATES
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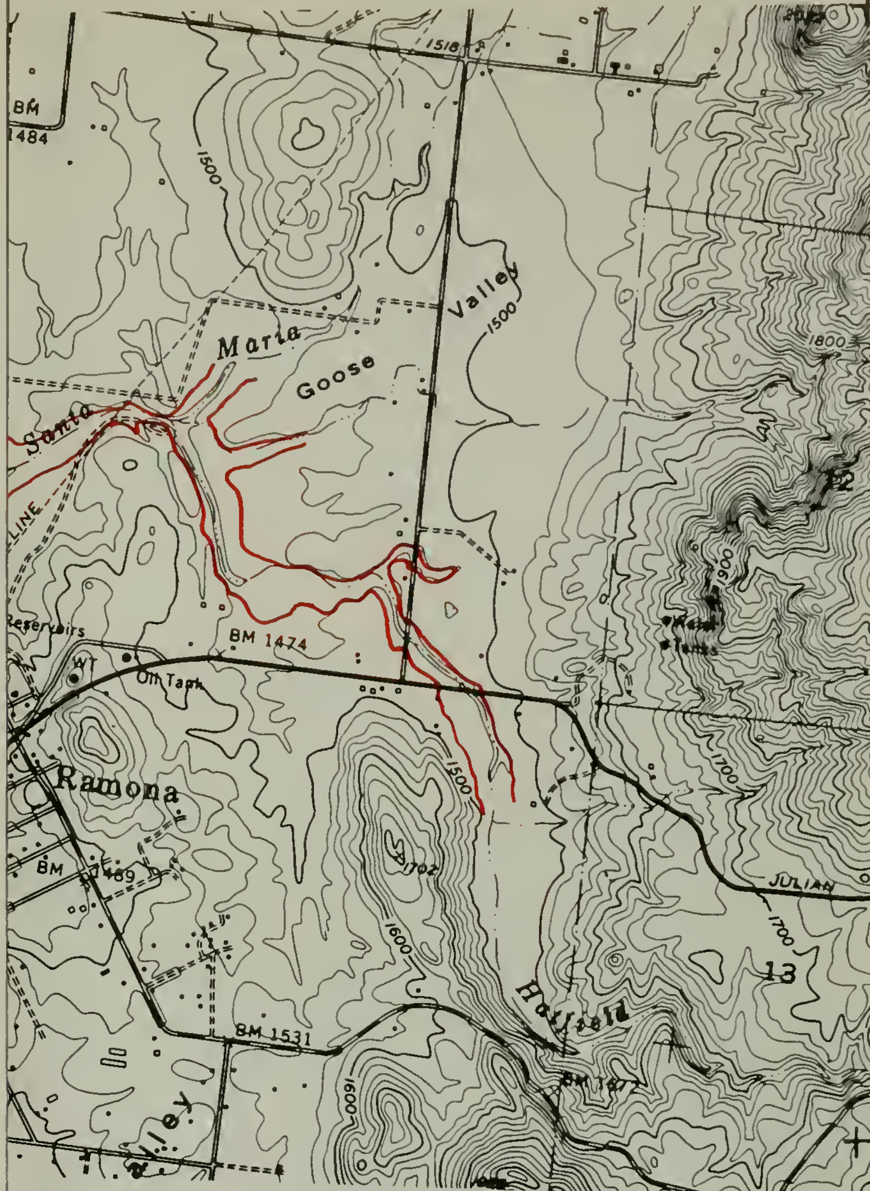
SANTA YSABEL CREEK
AREAS OF POTENTIAL INUNDATION
WITH RESERVOIRS HALF FULL INITIALLY

SCALE OF FEET
1000 0 1000 2000



EXPLANATION

INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
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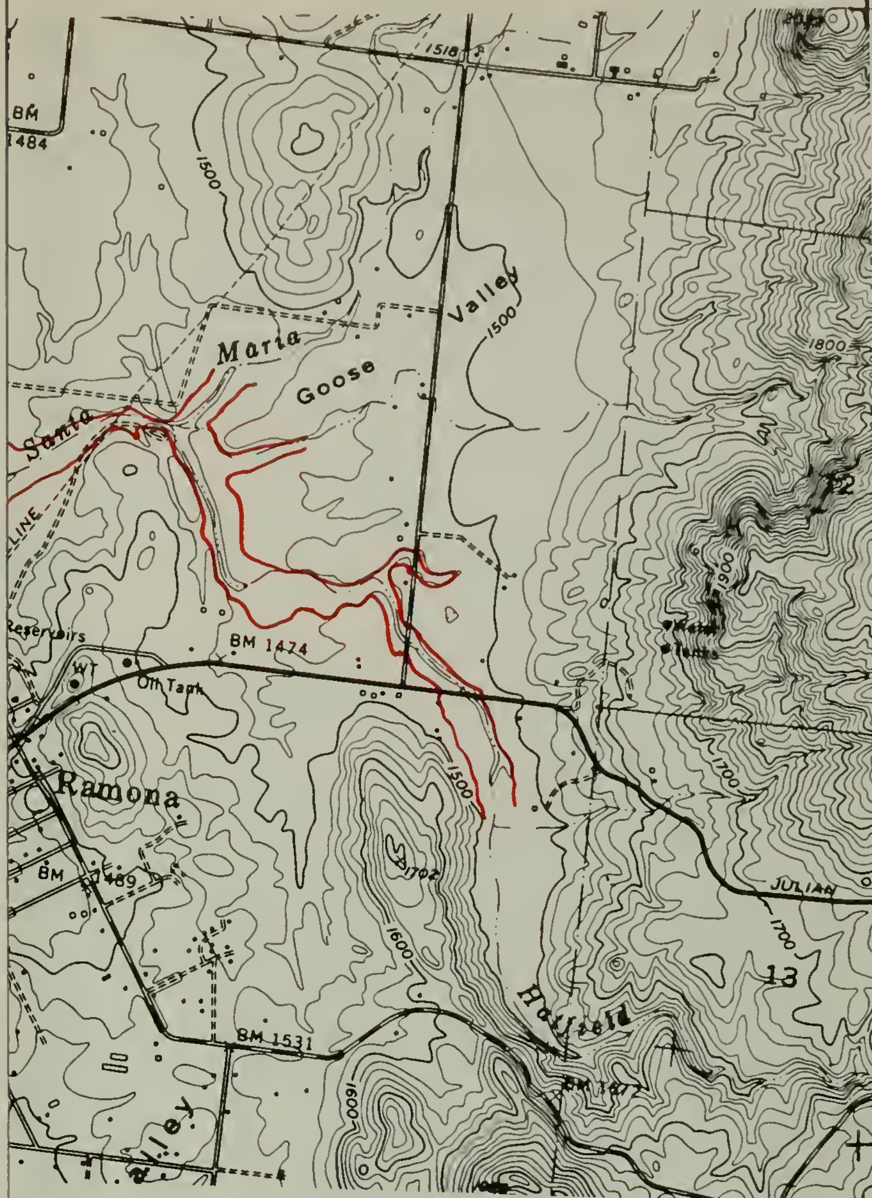
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SANTA MARIA CREEK
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000



EXPLANATION

INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

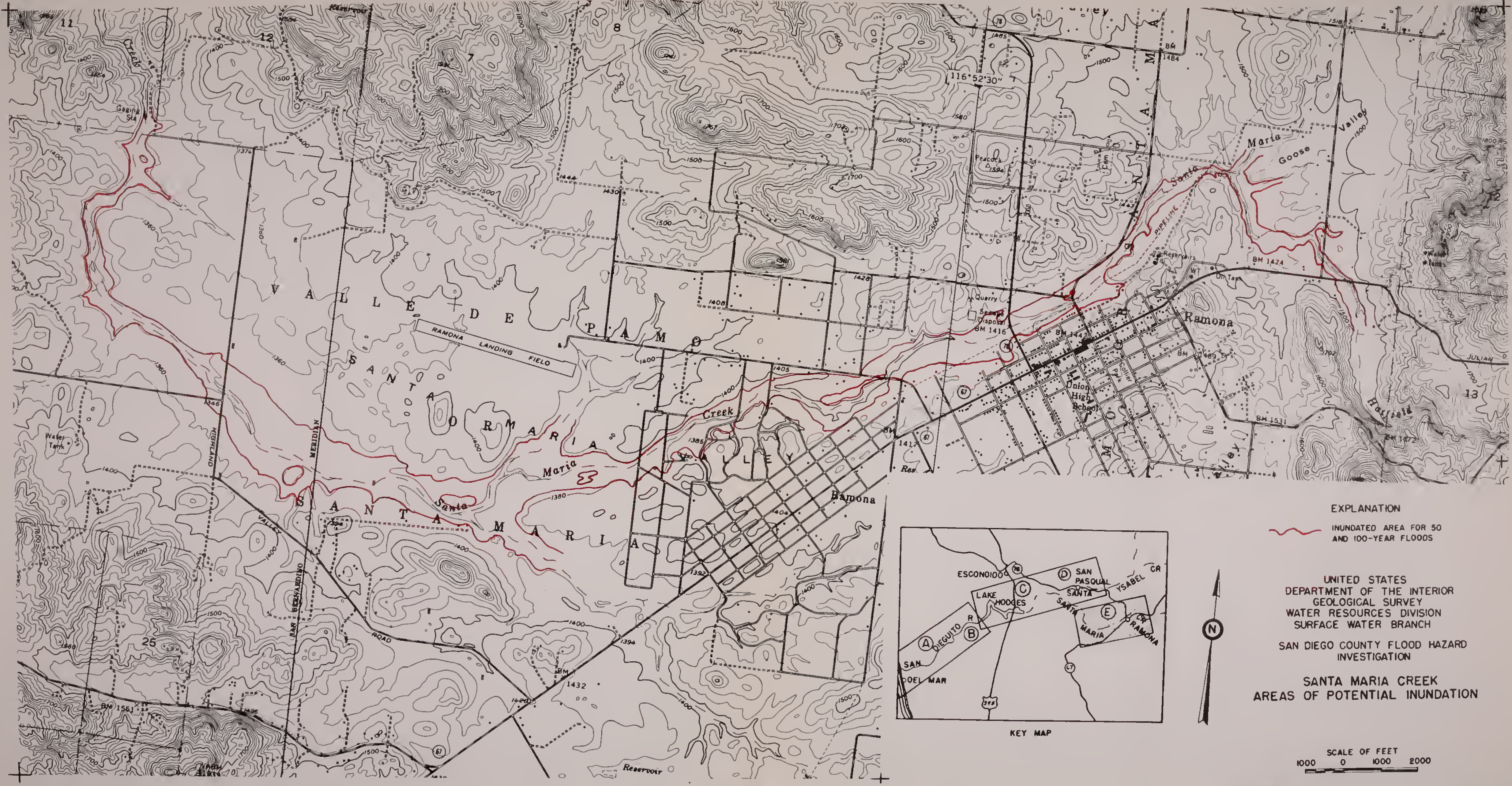
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SANTA MARIA CREEK
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000

PLATE 4-E1


EXPLANATION
INUNDATED AREA FOR 50 AND 100-YEAR FLOODS
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION
SANTA MARIA CREEK
AREAS OF POTENTIAL INUNDATION
SCALE OF FEET
1000 0 1000 2000
KEY MAP
ESCONDIDO
LAKE HODGES
SAN PASQUAL
SANTA YSABEL CR
SANTA MARIA
RAMONA
DIEGUITO R
SAN DIEGO DEL MAR
VALLE DE PAMO
SANTA MARIA VALLEY
SANTA MARIA
RAMONA LANDING FIELD
Santa Maria Creek
Ramona
Union High School
Santa Maria
Goose Valley
116°52'30"
HIGHLAND
MERIDIAN
SAN BERNARDINO
VALLEY ROAD
JULIAN
Hatfield
Reservoir
Gaging Sta
Water Tank
PIPELINE
Quarry
Sewage Disposal
BM 1416
BM 1424
BM 1531
BM 1561
BM 1484

APPENDIX G

AREAS OF POTENTIAL FLOOD INUNDATION
SAN LUIS REY RIVER BASIN, CALIFORNIA

(Prepared by U. S. Geological Survey)

APPENDIX G

AREAS OF POTENTIAL FLOOD INUNDATION
SAN LUIS REY RIVER BASIN, CALIFORNIA

(Prepared by U. S. Geological Survey)

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

AREAS OF POTENTIAL FLOOD INUNDATION
SAN LUIS REY RIVER BASIN, CALIFORNIA

by

H. A. Ray and L. E. Young

APPENDIX G
TO
BULLETIN 112
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

State of California
DEPARTMENT OF WATER RESOURCES

July 1963

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INTRODUCTION

Purpose and Scope

This report (Appendix G to State of California Department of Water Resources Bulletin 112 - San Diego County Flood Hazard Investigation) is part of a project to investigate the flood hazard along the flood plains of the five major rivers in San Diego County, California (fig. 1). The purpose of this report is to provide information on flood hazards along the San Luis Rey River. Similar reports are being prepared for the San Dieguito River, San Diego River, Otay River, and Sweetwater River.

There were two basic parts to this study. The first was the determination of peak discharge at key sites along the river for floods of two selected frequencies, namely, the 50-year flood and 100-year flood. As used in this report a 50-year flood is defined as a flood with a 2-percent probability of being equaled or exceeded in any year. A 100-year flood is similarly defined as having a 1-percent probability of being equaled or exceeded in any year. The second part of the study was the determination of the water-surface profile for both floods using topographic data from field surveys and large-scale county maps. The surface-water profiles were used to define areas of potential inundation.

The report is a source of flood information that provides a basis for establishing criteria to control encroachment on the San Luis Rey River flood plain. Areas subject to periodic inundation are delineated on 7½-minute topographic quadrangle maps that are included with this report.

The data and computations upon which this report is based are available in the files of the U.S. Geological Survey, Menlo Park, California.

The study was made by H. A. Ray and L. E. Young, under the general direction of Walter Hofmann, District Engineer in charge of surface-water investigations in California, with technical assistance by S. E. Rantz.

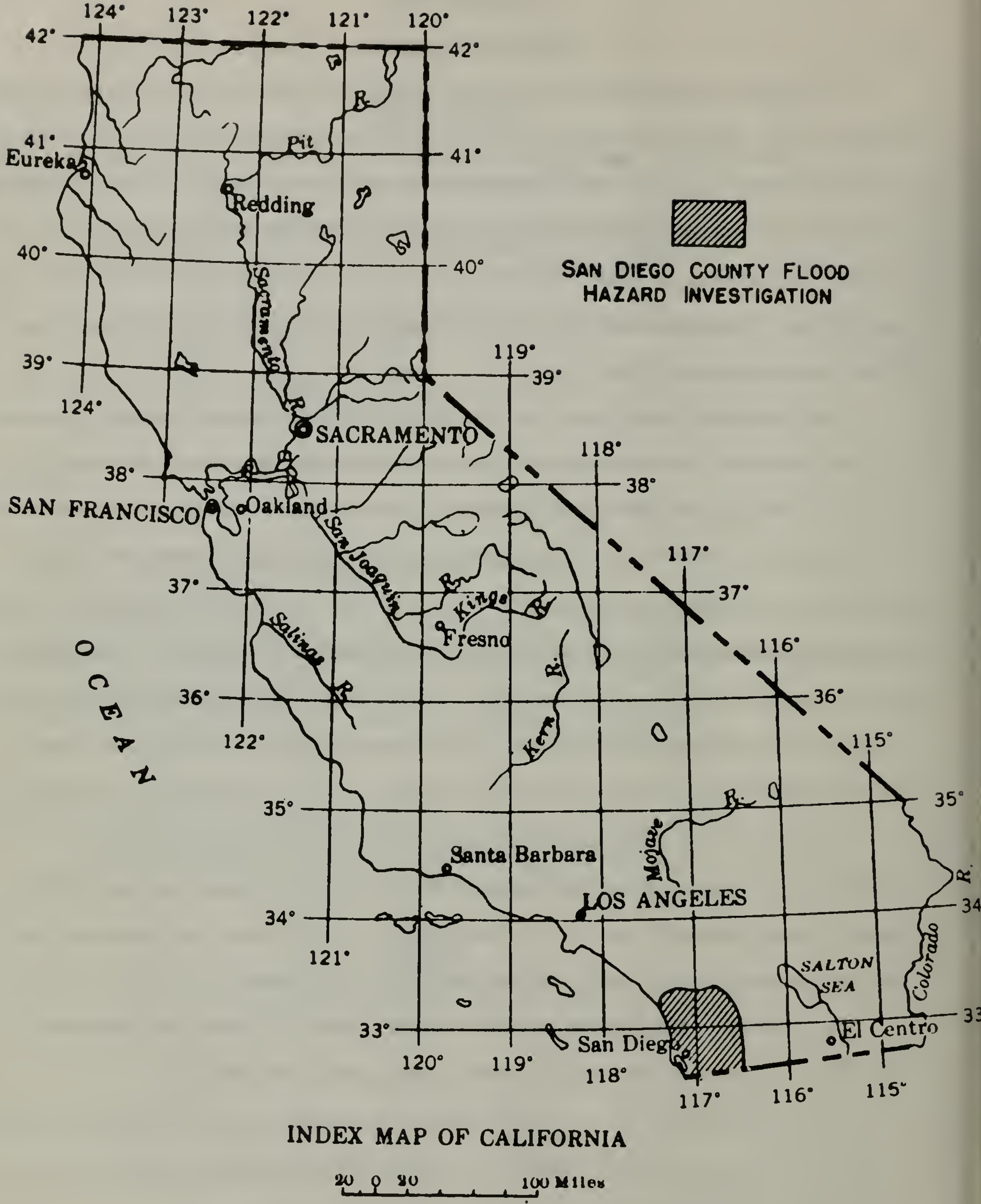


Figure 1.--Location of project area

Acknowledgments

The study described in this report was authorized by a cooperative agreement between the U.S. Geological Survey and the California Department of Water Resources for the investigation of flood hazards on two major rivers in San Diego County. The assistance of the California Department of Water Resources in processing the data for reservoir routing studies, providing a field survey crew, and printing the maps for this report is gratefully acknowledged. The helpful cooperation of the county of San Diego, Department of Special District Services, is also acknowledged.

Description of the Area

The San Luis Rey River system drains an area comprising 565 square miles lying wholly in the northern part of San Diego County. The area extends from the crest of the Coast Range to the Pacific Ocean, a distance of about 65 miles, and has a maximum drainage basin width of about 16 miles. The main stem is formed by many small streams which rise in the higher altitudes of the Coast Range and join at the lower or west end of what is locally known as Warners Valley. Upon completion of a large dam at this site in 1922, Lake Henshaw (capacity 194,323 acre-feet) was formed which controls the upper 206 square miles of drainage area. Below Lake Henshaw the river flows for about 10 miles through a deep, narrow canyon with a steep slope, then flows for about 40 miles over a wide sand and gravel flood plain of medium slope and finally discharges into the Pacific Ocean at Oceanside.

The drainage basin above Pala consists of moderate to steep rolling terrain and of valleys under cultivation. The more desirable valley areas are being subjected to increased encroachment by man. The drainage basin from Pala downstream to the Pacific Ocean consists of gently rolling terrain and wide valley flood plains normally under cultivation. However, considerable commercial and residental occupancy has taken place in recent years in the lower Mission

Valley (between Mission San Luis Rey and city of Oceanside).

In general, the entire basin is poorly forested with the greater part of the cover being brush and grass. The mean annual precipitation on the basin ranges from 10 inches along the foothills to more than 40 inches on the mountain slopes.

Large floods on streams in southern California are usually caused by masses of warm, humid air which sweep in from the Pacific Ocean during winter storms. Under certain meteorologic conditions, between 20 and 30 inches of rain may fall during a storm on the higher headwaters of the river basins in southern California. Such conditions were the cause of the large floods of 1916, 1927, and 1938.

PEAK FLOOD FLOWS

Regional Flood Frequency

A regional flood-frequency analysis for defining the relation between the magnitude and frequency of momentary annual peak flows of streams in the project area was made by the California Department of Water Resources and reviewed by the U.S. Geological Survey. The regional concept of flood-frequency analysis was adapted because flood-frequency relations derived from the combined experiences of a number of gaging stations in a homogeneous area are considered more reliable than those based on records for individual gaging stations, particularly those with short records. The flood series for any single gaging station is a random sample, and may not be representative of the long-term average distribution of flood events. A regional analysis defines relationships that are applicable to drainage areas of various sizes within a hydrologically homogeneous region. The techniques employed are only briefly discussed here as they are explained in detail in Appendix A, Bulletin 112.

Analytical Techniques

In a regional analysis of flood-frequency, it is essential that only the flood records for streams whose peak discharge was unaffected by man-made storage or diversion be used. Furthermore, a common length of record, or base period of years, must be used for all gaging stations. Reliability of the analysis depends on the length of the base period as well as on the accuracy of the records. Consequently, the longest base period possible was selected within the period of record of the earliest stations established. The base period chosen was the 55-year period, 1906-60. It was possible to extrapolate the flood-frequency curves beyond the base period because of the availability of qualitative historical records of major floods that occurred prior to 1906.

The methods of tabulating flood data commonly used in flood magnitude-frequency analyses are (1) the annual flood series, and (2) the partial-duration series. The annual series of flood peaks is used in preference to the partial-duration series. Although the partial-duration series is applicable to flood mapping studies, it has been shown (Dalrymple, 1950, p. 6) that the recurrence intervals obtained by the two series approach numerical equality for large floods. For this reason and because of the availability of annual peak data, the annual flood series was used in this study.

Because a common base period is required for all stations, those stations whose records are shorter than the base period required an estimate of the missing annual peak discharges. These estimates for the stations with short records were made by graphical logarithmic correlation with records for long-term stations that were in operation during the base period. In addition to records within the project area, records for nearby stations outside the area were used in developing the frequency analysis.

Method of Analysis

The method most commonly used by the Geological Survey in a regional flood-frequency analysis is the index-flood method (Benson, 1962, p. 16). This method consists of two major steps. The first is the development of basic dimensionless frequency curves representing the ratio of the flood of any frequency to an index flood which is generally the mean annual flood. The second step is the development of relations between hydrologic characteristics of drainage areas and the mean annual flood, so that the mean annual flood at any point within the region can be defined. By combining the mean annual flood obtained from the developed relations, with the dimensionless frequency curves, it is possible to develop a frequency curve for any location.

In a semi-arid region the index-flood method may be inadequate to estimate large flood peaks on the basis of the mean annual flood. This is particularly true of large basins where the mean annual flood may often result from a storm that affects only a part of the basin. An alternate approach (Benson, 1962, p. 20) is a method in which peak flows at selected recurrence intervals are related to hydrologic and physiographic characteristics of the basin by multiple-correlation techniques. This obviates the need of using an index flood, as individual regression equations are derived for each recurrence interval considered. A series of significant drainage basin parameters were tested for their relative significance in predicting floodflows. Briefly, the equations relating the T-year (any recurrence interval) peak discharge, Q_T, to various basin parameters, have the general form:

$$Q_T = a\ B^b C^c D^d \text{ --}$$

where

B, C, D, -- are the independent variables (basin parameters),

a, b, c, d, -- are constants of the regression equation

In the project area, it was found that the multiple-correlation technique of flood-frequency analysis gave more satisfactory results than the index-flood method; therefore the multiple correlation technique was used in this study. After several combinations of basin characteristics were analyzed by multiple regression analyses, the most significant regression equations for defining the 50- and 100-year floods for streams in the project area were found to be:

$$Q_{50} = 1016\ A^{.59}\ Sh^{-.44}$$

and

$$Q_{100} = 1288\ A^{.60}\ Sh^{-.57}$$

where

Q_{50} is the 50-year flood discharge, in cubic feet per second

Q_{100} is the 100-year flood discharge, in cubic feet per second

A is the drainage area, in square miles

Sh is a dimensionless basin shape factor.

The shape factor is defined as:

$$Sh = d/l$$

where

d is diameter, in miles, of a circle with an area equal to the basin area

l is length, in miles, of the drainage basin measured parallel to the principal stream channel.

As a convenience in determining the 50- or 100-year peak discharges, the results of the two multiple regressions are shown by a family of curves in Appendix A. To use the curves, the drainage area above the point for which flood peaks are to be determined and the basin length parallel to the course of the principal stream channel are required. These values can be obtained by a planimeter and a rule after outlining the appropriate basin area on a topographic map.

Routing Peak Flows

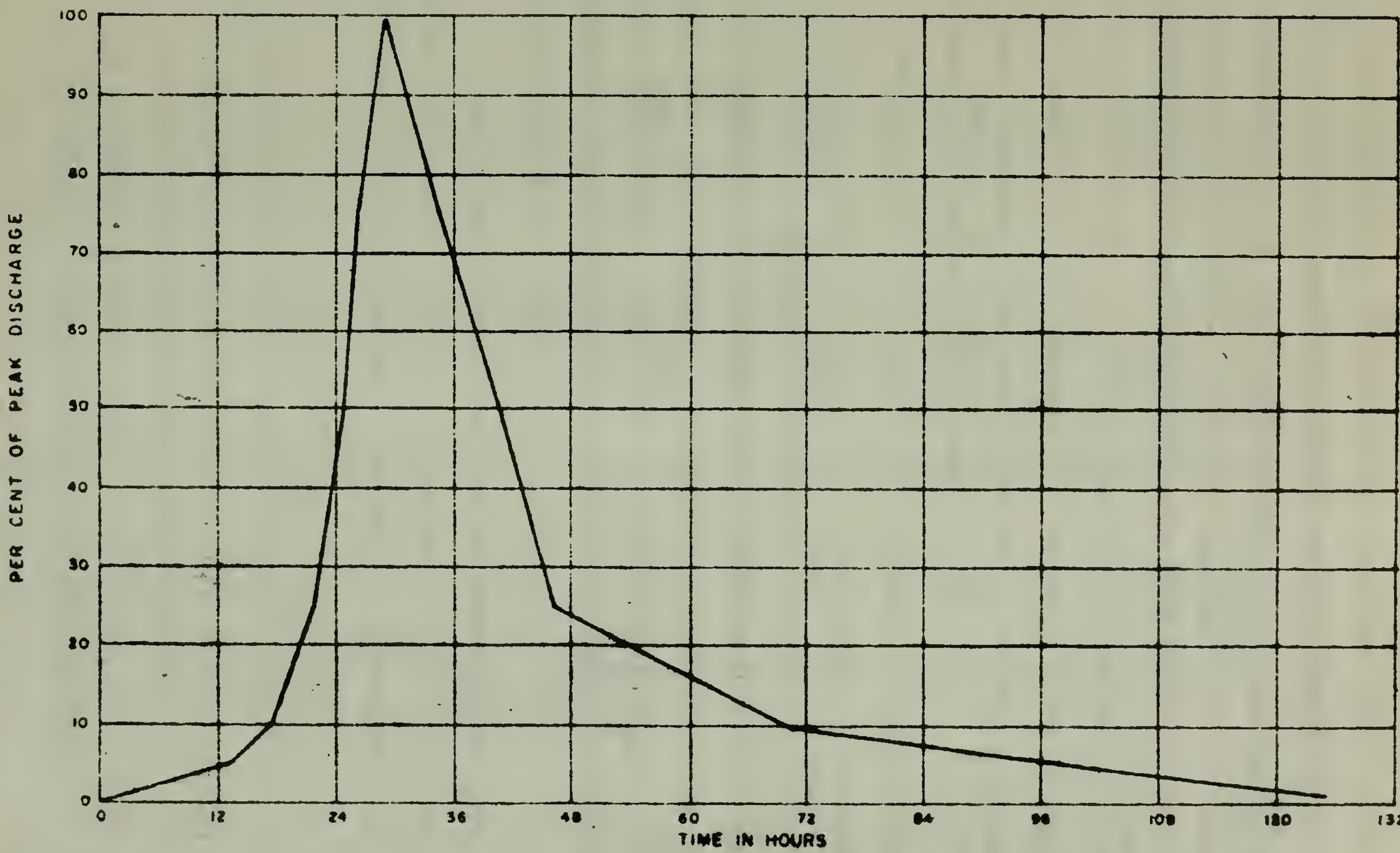
The equations of the previous paragraphs are derived from peak discharges that occurred under natural conditions, that is, uninfluenced by man-made developments in the basin. However, there is a major reservoir in the San Luis Rey River basin. To determine the effects of the reservoir on peak flows, it was first necessary to obtain a complete hydrograph for a flood event. For the San Luis Rey River, like most rivers in San Diego County, there are few recorded hydrographs of major floods. Therefore it was necessary to utilize flood hydrographs from other rivers in the area. A composite dimensionless flood hydrograph for San Diego County was developed on the basis of a few available recorded flood hydrographs for all major rivers in the area. This hydrograph, which has percent of peak discharge as the ordinate and time elapsed since beginning of storm runoff as the abscissa, is shown in figure 2.

Reservoir Flood Routing

River flows in the San Luis Rey River basin are regulated by Henshaw dam and reservoir (capacity 194,323 acre-feet). Based on the total volume of the average flood hydrograph (fig. 2) used in this report it is evident that Henshaw Reservoir would completely contain the 50- or 100-year flood peak, assuming the antecedent condition of the reservoir would be half-full at the beginning of runoff. The condition of Henshaw Reservoir being full at the time a major flood occurs is very improbable and no further study was made regarding magnitude of flood peaks for this condition.

The natural peak discharges for the 50- and 100-year floods in the basin below Lake Henshaw were determined by methods outlined in the California Department of Water Resources flood hydrology study of the project area.

FIGURE 2



AVERAGE FLOOD HYDROGRAPH FOR SAN DIEGO COUNTY

Table 1 lists peak discharges at selected points for the 50- and 100-year floods based on the effective drainage area of the river basin below Henshaw Dam.

Table 1.--Peak discharges in San Luis Rey River Basin

Location	Effective Drainage Area	Peak discharges, in cfs	
		50-year flood	100-year flood
Oceanside (mouth)	351	43,100	63,000
Near Bonsall (USGS gage)	306	36,000	51,500
Monserate Narrows (USGS gage)	168	28,000	40,000
Near Pala (USGS gage)	112	21,700	31,000
Above Aqua Tibia Creek confluence	98.6	20,000	28,500
Above Pauma Creek confluence	77.2	17,400	24,500
Near Nellie (USGS gage)	33	9,500	12,800

CHANNEL HYDRAULICS AND BACKWATER COMPUTATIONS

Stream Characteristics

Beginning in 1943 and continuing to the present (1963) the San Luis Rey River watershed has experienced the most severe drought of record. As a result of long periods of no flow, continued vegetal growth has reduced the streamflow capacity of the main channel. This is not critical in the narrow mountain canyons where floodflows are confined between the canyon walls. Along the wide coastal plain, however, a flood occurring now would spread across more of the flood plain than it would have before the reduction in the main-channel carrying capacity. Consequently, potential flood damage threatens agricultural, business, or residential occupancy in these areas.

The purpose of this study is to delineate areas that will be inundated by a hypothetical 50-year or 100-year flood. Hypothetical flood boundaries are defined from water-surface profiles that are computed from channel cross sections. Cross sections of the river channel and flood plain were taken from large-scale maps (1 inch equals 200 feet) or obtained by field survey methods at selected points along the river. These data comprise an essential part of the standard method of backwater analysis which was used to determine the resultant water-surface profiles for the 50- and 100-year floods.

The basic equation used in computing water-surface profiles is the Manning equation which requires not only a knowledge of the channel geometry but also an estimate of the channel roughness. The Manning equation is:

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

where Q is discharge, in cubic feet per second

n is coefficient of roughness

A is the cross-sectional area, in square feet

R is hydraulic radius, in feet

S is slope of the energy gradient line, in feet per foot

Roughness Coefficients

The roughness coefficient, "n", used in the Manning discharge equation, is affected primarily by the following factors: bed roughness, vegetation, channel irregularity, channel alinement, filling and scouring, and stage.

For several years a continuing effort has been made by the Geological Survey to widen the range of knowledge with respect to Manning's "n" or roughness coefficient values for open channels. Indirect measurements of discharge are made under favorable conditions, where the discharge is known. The formulas are then used with known discharge values to compute the value of "n". These computed "n" values serve as a guide for selecting the roughness coefficients for similar channels. Stereo-photographs of the channels for which the "n" values have been verified are available for photographic comparison with the channel under study.

All roughness coefficients used in the backwater analysis were selected by the engineers of the Geological Survey. Stereo-photographs were taken to implement field reconnaissance notes and to compare them with photographs of similar channels with verified "n" values. In the narrow, steep canyon reaches the 50- and 100-year floods are confined in a channel with a somewhat trapezoidal cross section, having no appreciable flood plain. Roughness coefficients for these reaches are fairly high, ranging from about 0.06 to as high as 0.10 where the brush, trees, and boulders predominate.

For flood stages on the flat, wide valley floors, the main channel is usually a very small part of the river cross section. The "n" values for these reaches range from about 0.03 for the main channel to as high as 0.05 for the wide flood plain with shallow depths. The "n" value for the flood plain usually decreases rather rapidly with increase in depth to a value of about 0.03.

Standard Step Method of Backwater Computation

The standard step method of backwater computation has been used to compute the profiles necessary to determine the extent of flooding by the hypothetical floods. The data necessary for its use are:

1. Discharge for which the profile is desired.
2. A water-surface elevation at the downstream end of the desired reach.
3. The cross-sectional area and hydraulic radius at various points along the channel for all depths of flow within the range expected.
4. The hydraulic roughness of the channel.

The discharges for the 50- and 100-year floods were obtained from the regional flood frequency study.

Starting at a section at the downstream end of the reach where the discharge and corresponding water-surface elevation are known, an estimate is made of the water-surface elevation at the next section upstream. The hydraulic radius and velocity head can then be computed at each section and the Manning equation used to route the flow upstream, thereby obtaining a water-surface elevation at the upstream section. If this computed elevation does not check the elevation that was previously estimated, a new estimate is made of the water-surface elevation and the process is repeated until the estimated and computed elevations agree. This procedure is then repeated in the next reach upstream.

Constrictions imposed on a natural river channel and flood plain usually cause some increase in the water-surface elevation upstream. All bridges in the reaches of river under study were investigated for their effects, if any, on the water-surface profiles. Methods outlined in Geological Survey Circular 284 (Kindsvater and others, 1953) were used in the analyses. The water-surface profiles were first computed by using the natural channel cross sections and then the effects of bridge constrictions were computed and the profiles adjusted accordingly.

The Geological Survey has developed a program for computing backwater profiles for tranquil, gradually-varied flow, using an electronic computer. The program is set up to compute water-surface profiles for as many as 10 different discharges at one time. Use of the computer greatly expedited this study.

Stage-Discharge Relation

San Luis Rey.--The reach of stream from below Highway 101 to the Ocean was considered unsatisfactory for machine computation of backwater. Therefore, a stage-discharge relationship was determined by the slope-conveyance method at a representative river cross section just upstream from the present Highway 101 bridge. The slope-conveyance method utilizes the Manning equation, where $Q = KS^{\frac{1}{2}}$. The conveyance ($K = \frac{1.486}{n} AR^{2/3}$) can be computed from cross section properties, and the energy slope S, assumed to be parallel to the channel slope for this particular computation, can be measured in the field or from topographic maps.

Moosa Canyon Tributary.--Moosa Canyon tributary joins the San Luis Rey main stem at Bonsall. This tributary drains an area of about 42 square miles and parts of the flood plain may be subject to considerable future development. For this reason it was decided to delineate the areas of inundation from the mouth of the tributary upstream to the vicinity of Highway 395. The initial stage-discharge relation at the mouth of Moosa Canyon was obtained by using the water-surface profile for the 50- and 100-year floods for the San Luis Rey River as determined by previous backwater computations. Water-surface profiles for the reach of Moosa Canyon under investigation were then determined by the standard step method of backwater analysis.

AREAS OF POTENTIAL INUNDATION

Water-Surface Profiles

Water-surface profiles for the 50- and 100-year floods were computed by the standard step method of backwater analysis. The stage-discharge relations, as explained in the preceding section, were used in conjunction with hydraulic properties of the channel at cross sections located at strategic points along the San Luis Rey River system. Generally, the cross sections were located about 2,000 feet apart but the distance varied depending on the hydraulic properties of the particular reach under consideration. The water-surface profiles were adjusted for the effect of bridge constrictions where necessary, namely, Camp Pendleton Road bridge near San Luis Rey and Highway 395 bridge east of Bonsall.

Because of the complex channel geometry of the San Luis Rey River from its mouth to the present Highway 101 bridge, it was considered not feasible to apply the standard step backwater computations in this reach of the channel. The section entitled "Special Conditions Below Highway 101" contains a qualitative discussion regarding the extent of potential flooding for this reach of the river.

Extent of Flooding

The extent of flooding in the river basin by the 50- and 100-year peak flows is shown on strip maps which were prepared from Geological Survey 7½-minute topographic quadrangles for the project area. Plate 5-A shows the San Luis Rey river from its mouth to above Camp Pendleton Road Crossing. Plate 5-B denotes the inundated areas from above Camp Pendleton Road crossing to the Fallbrook-Vista Road. Plate 5-C features the reach of the San Luis Rey in the vicinity of the city of Bonsall and that part of Moosa Canyon for which flood boundaries were determined. Plate 5-D shows the reach of stream from just below present Highway 395 Crossing to below Pala, California. Plate 5-E covers the San Luis Rey from just below Pala upstream to lower Pauma Valley. Plate 5-F completes the area of inundation upstream through Pauma Valley to the confluence of Paradise Creek and the San Luis Rey River near the Rincon Springs community. No further flood profiles were deemed necessary in the fifteen miles upstream to Henshaw Dam because the river is confined in a narrow mountain valley at all stages.

Flood inundation boundaries have been determined by using the computed water-surface profiles and selected cross sections of the river. The edge of the water at each end of a particular cross section occurs where ground and water elevations are identical. Flood boundary lines are then drawn through these points, using the map contours as a control between cross sections, and field checking where necessary. A grid of elevations to the nearest foot or one-half foot appears on the large-scale (1 inch equals 200 feet) maps so that for areas covered by these maps, flood boundaries between cross sections were more easily determined.

Special Conditions Downstream from Highway 101 Bridge

In the 3,000-foot reach of the San Luis Rey River between the present Highway 101 bridge and the mouth, a situation exists which obviates use of machine computations for determining water-surface elevations. Although the river flood plain is spanned by the Highway 101 bridge and the Atchison, Topeka and Santa Fe Railroad Bridge, neither bridge structure offers an appreciable constriction and, therefore, can be ignored with regard to backwater effects on floodflows. As part of the city of Oceanside Marina project, considerable channel reduction has occurred both above and below the Atchison, Topeka and Santa Fe Railroad bridge. Retaining levees composed of earth fill behind heavy stone riprap have been constructed so that the carrying capacity of the flood plain is drastically reduced. Such conditions will undoubtly cause higher water-surface elevations than before, should a large flood occur. Also, sand deposits caused by ocean tides and littoral currents partly block the mouth of the stream. It is assumed that as soon as the sand bar is overtopped by floodwaters, it will be washed out rather rapidly. For this reason it is probable that the floodwaters will not rise to any great height above the elevation of the top of the sand bar at the time of flooding. The flood plain, immediately downstream from and south of the railroad bridge, will probably be inundated by a flood of large magnitude with resulting damage to the area.

Owing to the fact that half-tide level (average of mean low and mean high tides) is only about 3 feet above mean sea level, it is improbable that the elevation of floodwaters would be increased by normal tidal conditions. However, the highest tide recorded along the southern California coast in recent years is about 8 feet, and should a tide of this magnitude occur simultaneously with a peak discharge having a 50- or 100-year recurrence interval, the floodwaters would rise high enough to inundate a larger area. Also, a combination of high tide and strong wind, with resultant wave action would cause the floodwaters to rise above that elevation which would occur from average tidal conditions.

HISTORICAL FLOODS IN SOUTHERN CALIFORNIA

This report would not be complete without some mention of notable floods that occurred in the past in the San Luis Rey River basin.

Since 1770 flood runoff from the Coast Ranges has been observed and records of floods are found in a wide variety of publications. Only through judicious consideration of these past floods can plans be formulated for protection from, and control of, future floods which will inevitably occur. In spite of the application of our most advanced technical and scientific knowledge of flood-control practices, those who occupy natural flood channels and flood plains will be exposed to damages from floodwaters from time to time. The earliest references to floods in southern California streams are found in diaries and records of the Spanish Mission Fathers. Official weather observations in southern

California were begun in 1851 at San Diego. The first known estimate of flood discharges was made for a flood of 1889 on the Los Angeles River. The measurement of the flow of streams in California was begun on a very restricted basis in 1878 by the California State Engineer. The U.S. Geological Survey established a gaging station on the San Gabriel River near Azusa in 1894 and has gradually extended the work of collecting streamflow records throughout the State; many records have also been collected by private individuals.

Data indicate that major floods probably occurred in 1821 and 1851 on the San Luis Rey River and later records specifically mention major floods occurring in 1862, 1884, 1889, 1891 and 1916. Father Doyle of Pala Mission, interviewed shortly after the January 1916 floods, stated that it was the greatest flood to occur since the valley was settled. He rated the flood of 1862 as second greatest, and the flood of 1884 as third.

Edward R. Bowen, in a paper on the San Luis Rey floods of January 1916 says:

> "The entire San Luis Rey Valley was inundated, the stream extending from hill to hill, a distance of probably 1½ miles -- and covering an area of over 1,000 acres. The drift along the county road on the south side of the valley indicated a 6-foot depth of water at that point.***
>
> All farms in the valleys of the lower river were completely destroyed and three people were drowned. The entire valley is covered with deposit of sand and silt to an average depth of at least 3 feet, and in many places as much as 6 feet. Conditions along the upper river are not so bad. The valleys are more constricted and the stream better confined, although all crops along the bottom lands have been ruined."

Plates 1, 2, and 3 show damages at various points along the river basin caused by the 1916 floods. The peak discharge of the 1916 flood is considered to be greater than the 100-year flood discharge as determined by the regional flood-frequency analysis used in this report. The historical information and the pictures included in this report are the results of a limited search made during the field investigations for this project.

SUMMARY

The flood hazard along the San Luis Rey River, one of the five principal streams in San Diego County, has been investigated using peak discharges for hypothetical floods having 50- and 100-year recurrence intervals. These peak discharges were determined by a regional flood-frequency analysis of streamflow records in and adjacent to the project area. A composite dimensionless hydrograph, based on available recorded flood hydrographs for all major rivers in the area, was developed to determine the volume of runoff associated with the 50- and 100-year floods. Our studies indicate that Henshaw Reservoir due to its enormous storage capacity would completely contain the 50- or 100-year floods assuming that the antecedent conditions of the reservoir would be half-full at the beginning of runoff. The condition of Henshaw Reservoir being full at the time a major flood occurs is very improbable and no study was made regarding the magnitude of flood peaks for this condition.

The natural peak discharges based on the effective drainage area of the river system below Henshaw Dam are used to determine areas of inundation.

The areas of the San Luis Rey River flood plain that will be inundated by floods of a 50- or 100-year magnitude and frequency are delineated on the maps included with this report. To define these areas it was first necessary to obtain cross sections and channel roughness coefficients for many points.

These data were processed by the standard step method of backwater analysis to compute the water-surface profiles for the 50- and 100-year floods. The areas of potential inundation were delineated from these water-surface profiles for the selected floods.

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Atchison, Topeka and Santa Fe Railroad Bridge at Oceanside, Calif. After the Floods of January, 1916.

U. S. Highway 101 Bridge over the San Luis Rey River at Oceanside, Calif.
BEFORE Floods of January, 1916.

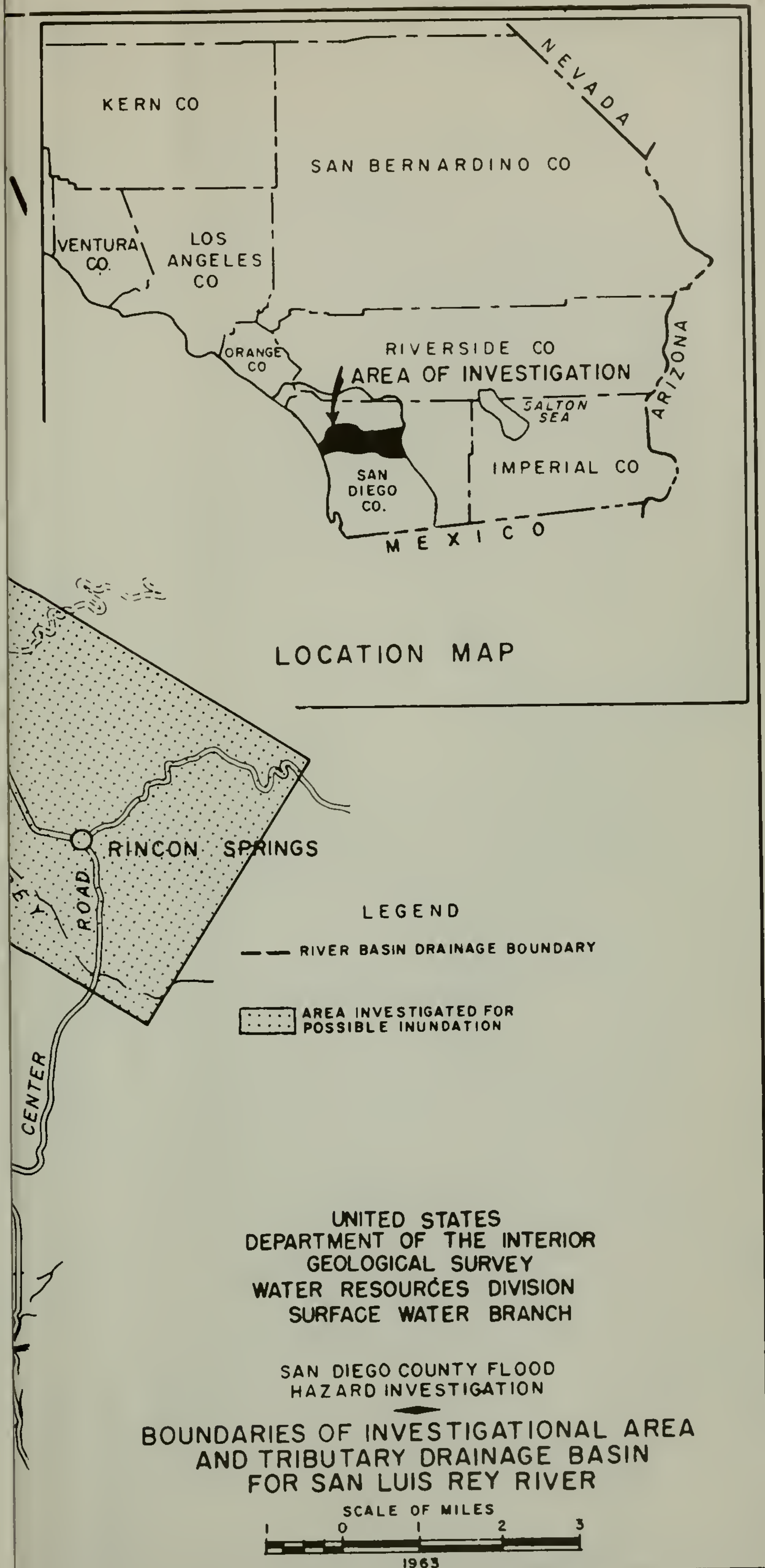
U. S. Highway 101 Bridge over the San Luis Rey River at Oceanside, Calif.
AFTER Floods of January, 1916.

GPO 966778

View from Rosicrucian Hill (Oceanside, Calif.) upstream toward Mission San Luis Rey after Floods of January, 1916.

From: Robert A. Weese, Supt., Water and Sewer Dept., City of Oceanside, Calif.

View of San Luis Rey River flood plain after Floods of January, 1916.



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

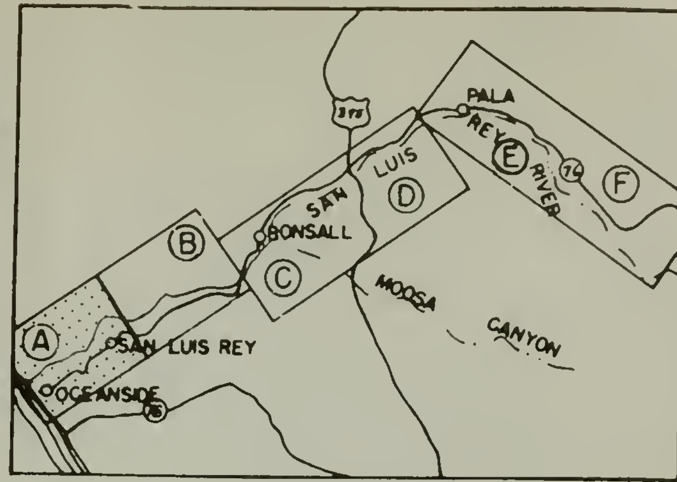
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

BOUNDARIES OF INVESTIGATIONAL AREA AND TRIBUTARY DRAINAGE BASIN FOR SAN LUIS REY RIVER

1963

RAINBOW
MISSION ROAD
FALLBROOK
RIVER
MARGARITA
O'NEIL LAKE
MISSION
ROAD
SANTA
BONSALL
Moosa
WINDMILL LAKE
PICO LAKE
FOSS LAKE
SAN
LUIS
REY
RIVER
WAY
VISTA
EAST
OCEANSIDE
VISTA
PACIFIC
OCEAN
PECHSTEIN LAKE
VISTA
CANAL
Canyon
VALLEY CENTER
VALLEY CENTER ROAD
COLE
VALLEY
CENTER
LAKE WOHLFORD
PALA
SAN
LUIS
GRADE
REY
ROAD
RINCON SPRINGS
101
76
78
395
A
B
C
D
E
F
N
KERN CO
SAN BERNARDINO CO
NEVADA
VENTURA CO
LOS ANGELES CO
RIVERSIDE CO
ORANGE CO
AREA OF INVESTIGATION
SALTON SEA
ARIZONA
SAN DIEGO CO.
IMPERIAL CO
MEXICO
LOCATION MAP
LEGEND
RIVER BASIN DRAINAGE BOUNDARY
AREA INVESTIGATED FOR POSSIBLE INUNDATION
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH
SAN DIEGO COUNTY FLOOD
HAZARD INVESTIGATION
BOUNDARIES OF INVESTIGATIONAL AREA
AND TRIBUTARY DRAINAGE BASIN
FOR SAN LUIS REY RIVER
SCALE OF MILES
1 0 1 2 3
1963

PLATE 5-A



KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
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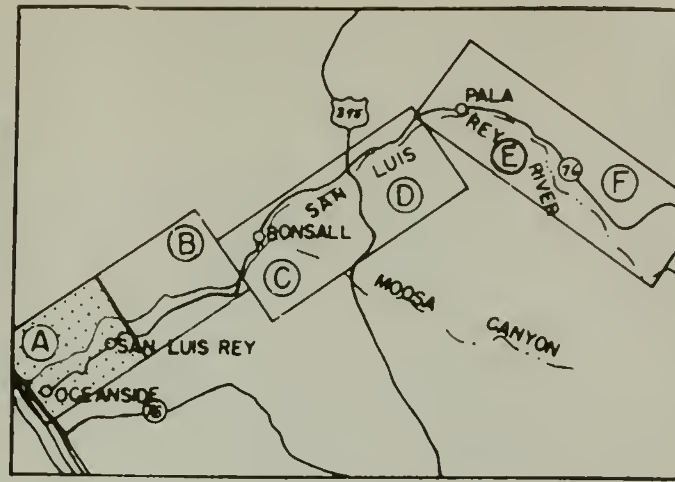
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN LUIS REY RIVER
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000



KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

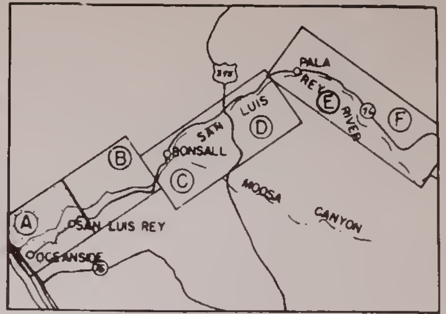
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN LUIS REY RIVER
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000

PLATE 5-A



KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
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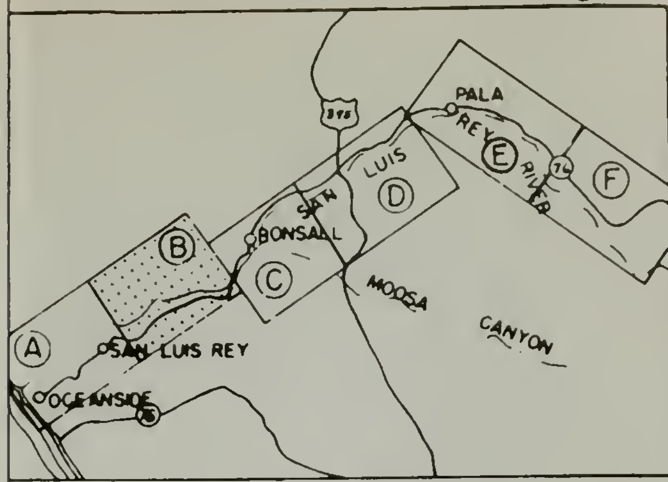
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

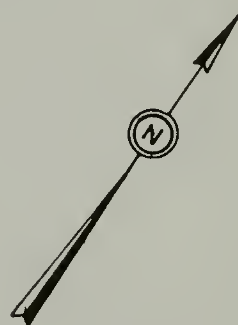
SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN LUIS REY RIVER
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000



KEY MAP



EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
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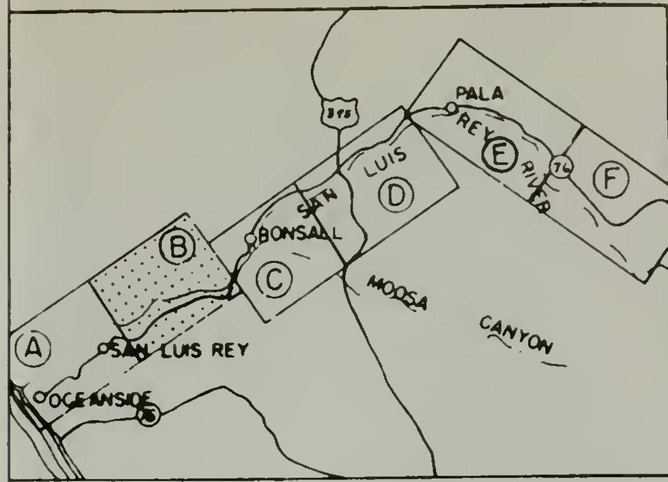
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

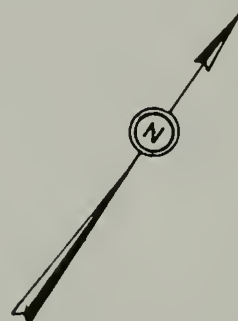
SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN LUIS REY RIVER
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000



KEY MAP



EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

INUNDATED AREA FOR 50-YEAR FLOOD

UNITED STATES
DEPARTMENT OF THE INTERIOR
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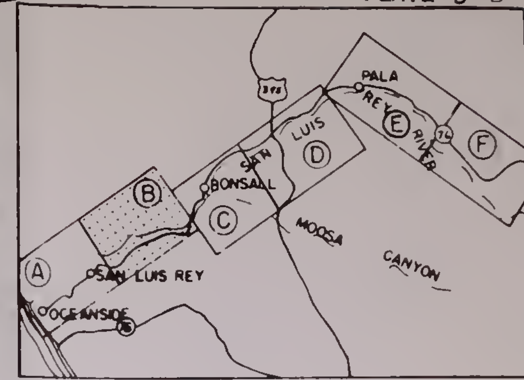
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

SAN LUIS REY RIVER
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000



KEY MAP

EXPLANATION

INUNDATED AREA FOR 100-YEAR FLOOD

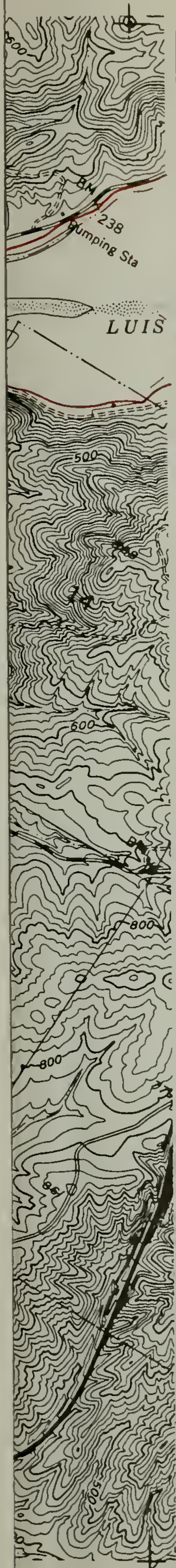
INUNDATED AREA FOR 50-YEAR FLOOD

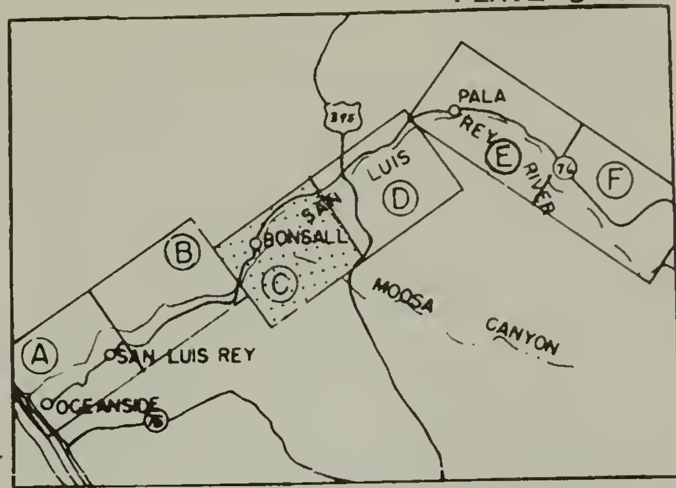
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD
INVESTIGATION

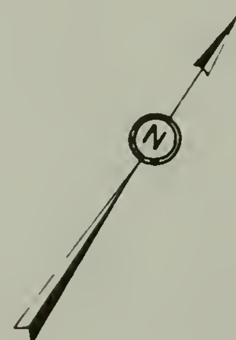
SAN LUIS REY RIVER
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000





KEY MAP



EXPLANATION

INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

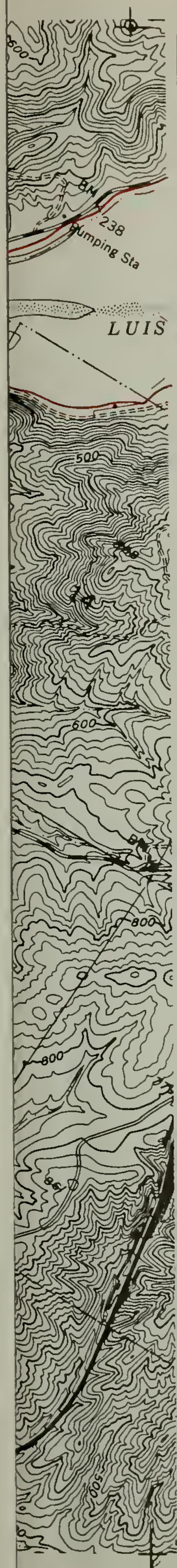
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

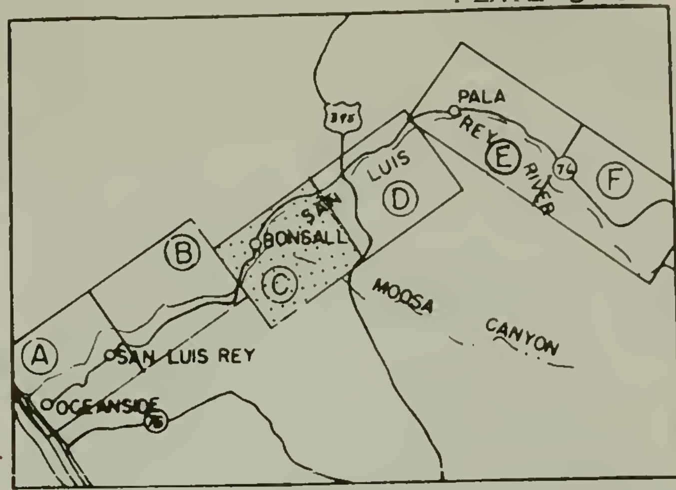
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN LUIS REY RIVER AND MOOSA CANYON TRIBUTARY AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000

PLATE 5-C





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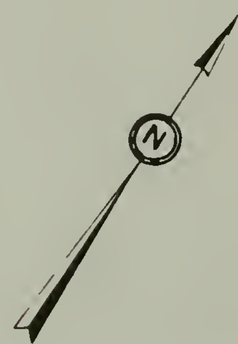


EXPLANATION

INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

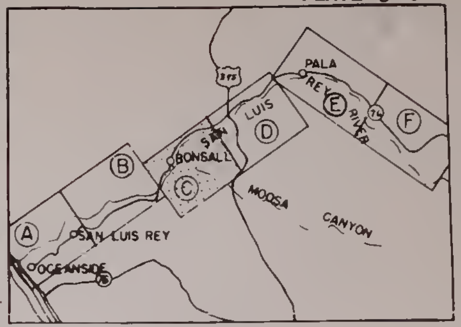
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
SURFACE WATER BRANCH

SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN LUIS REY RIVER AND
MOOSA CANYON TRIBUTARY
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET

1000 0 1000 2000



KEY MAP

EXPLANATION

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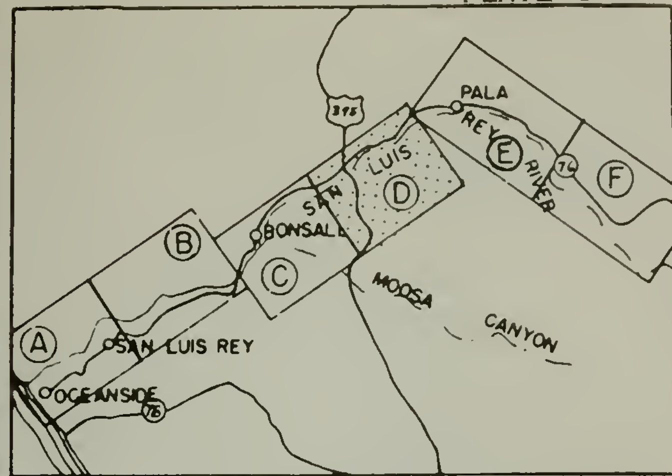
SAN LUIS REY RIVER AND
MOOSA CANYON TRIBUTARY
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000

PLATE 5-D



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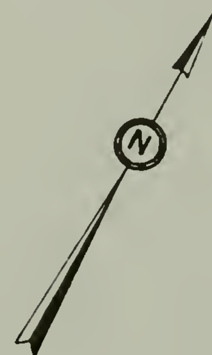

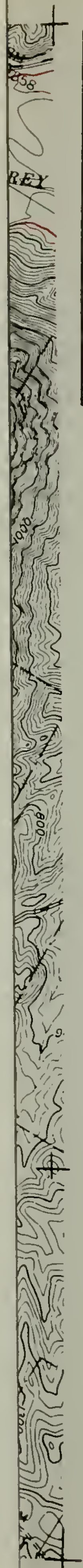

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SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN LUIS REY RIVER
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
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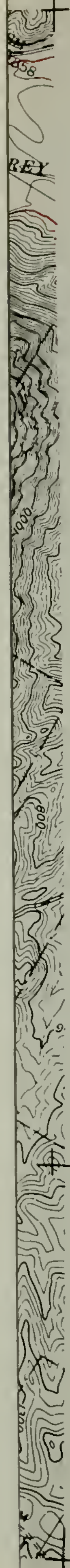

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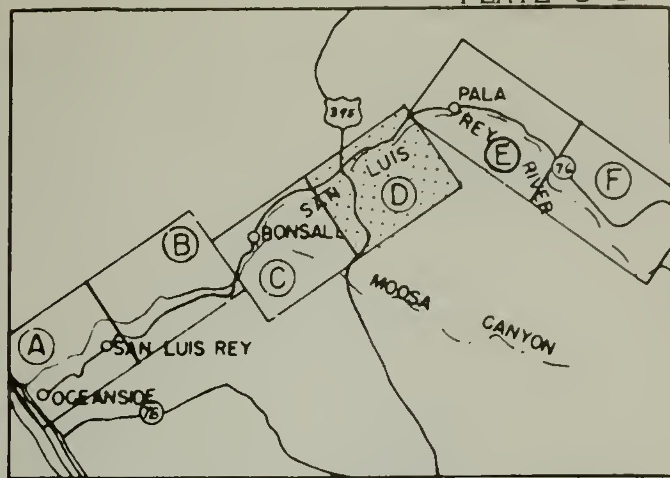

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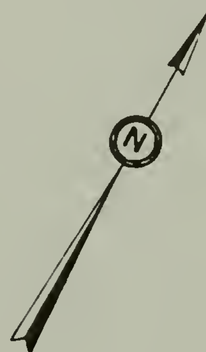

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AREAS OF POTENTIAL INUNDATION

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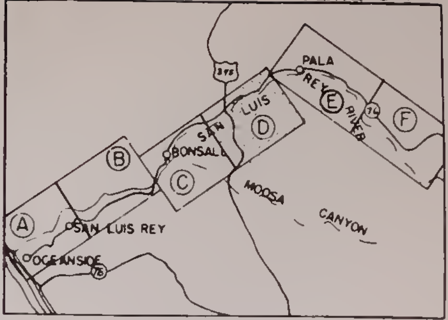

KEY MAP

EXPLANATION

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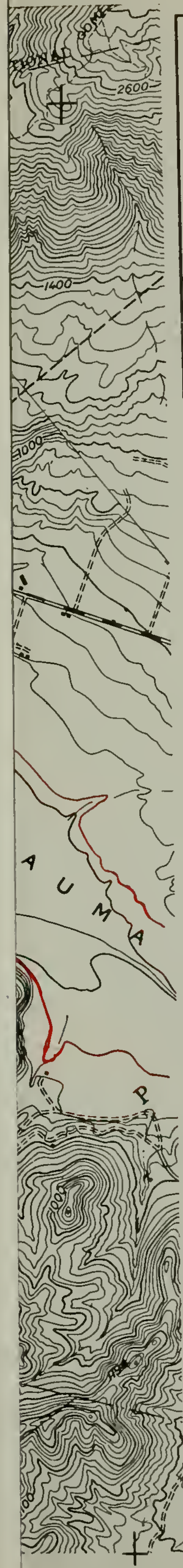

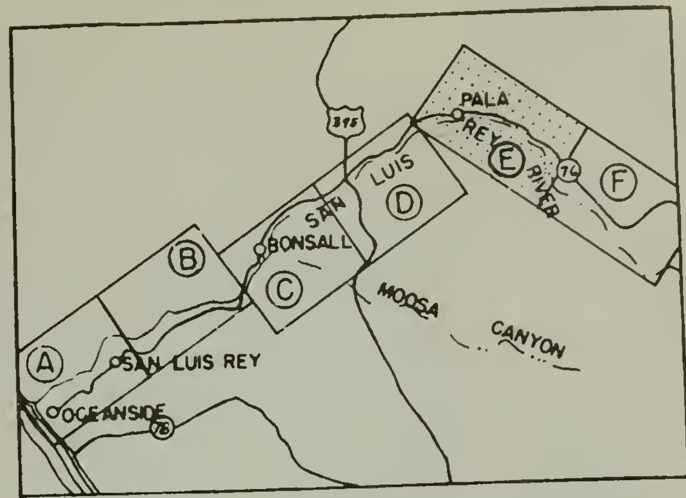

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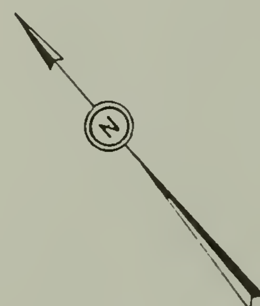

EXPLANATION

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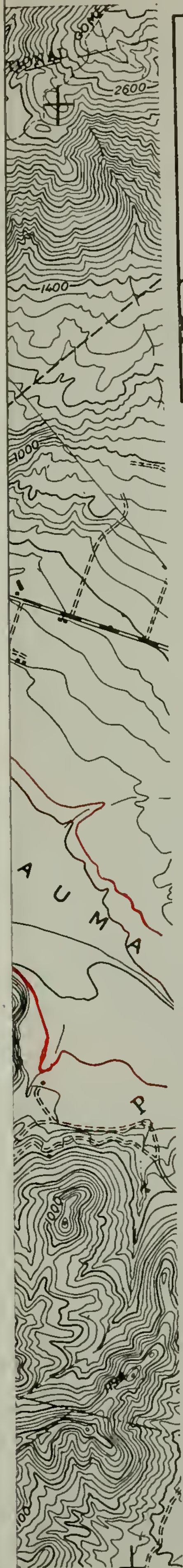

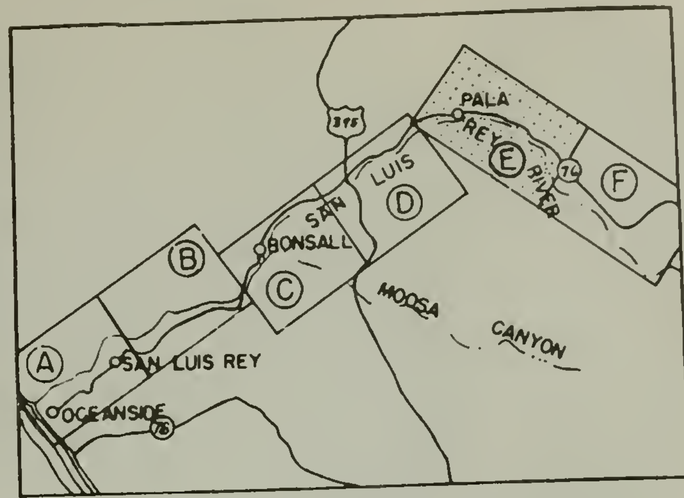

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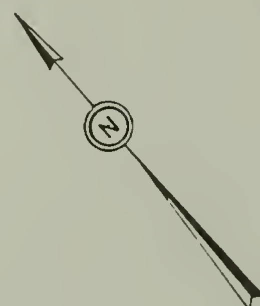

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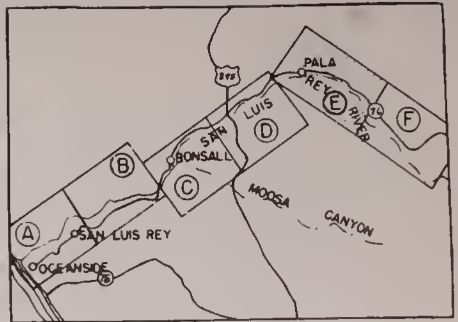

KEY MAP

EXPLANATION

INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

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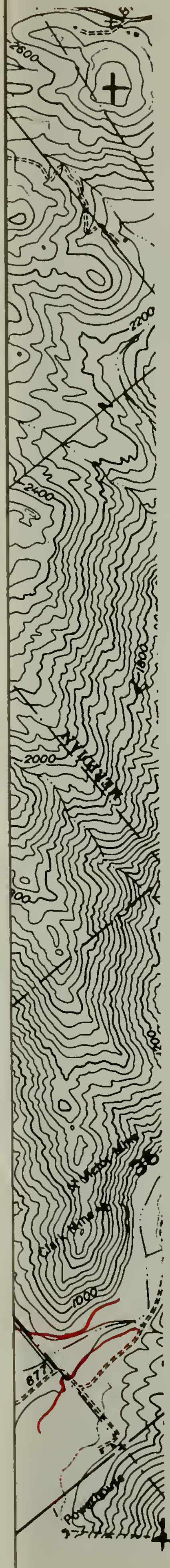

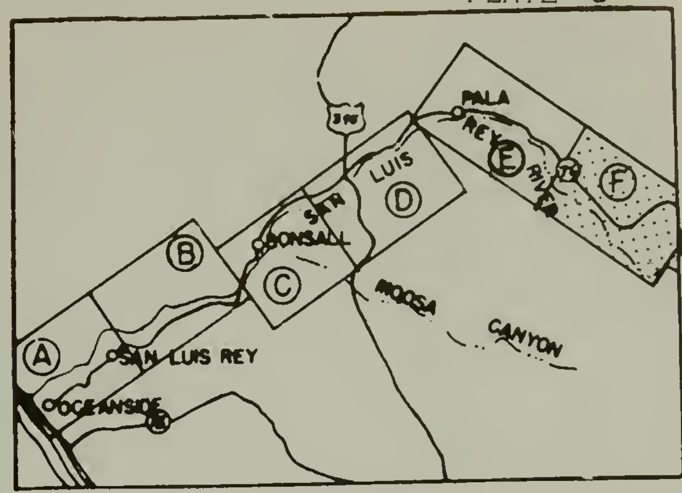

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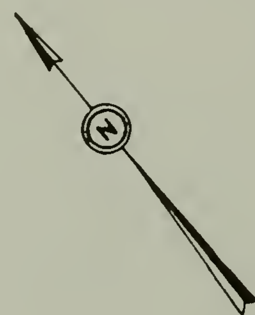

EXPLANATION

INUNDATED AREA FOR 50 AND 100-YEAR FLOODS

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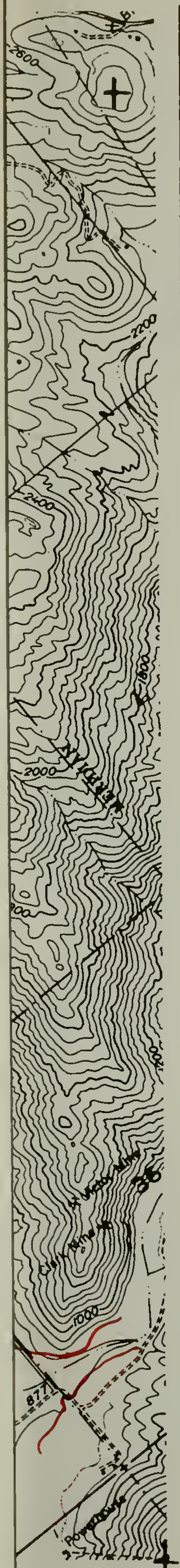
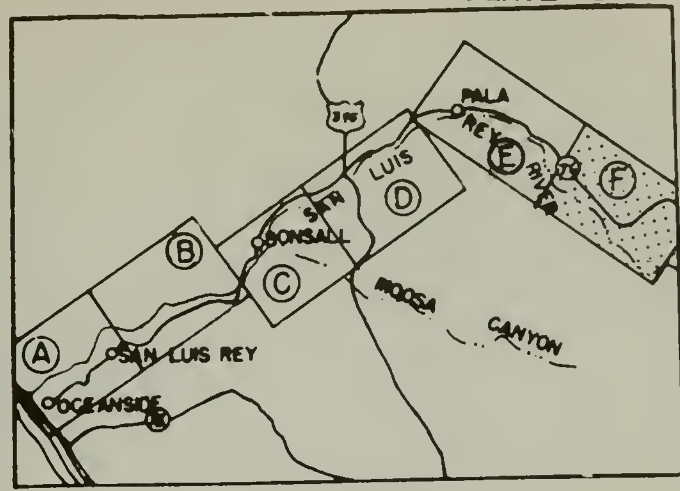
SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

SAN LUIS REY RIVER
AREAS OF POTENTIAL INUNDATION

SCALE OF FEET
1000 0 1000 2000

PLATE 5-F





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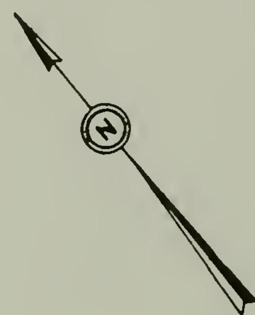

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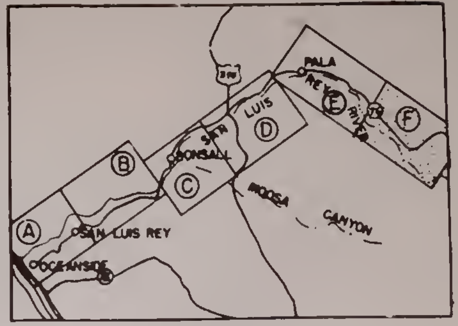

KEY MAP

EXPLANATION

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SAN DIEGO COUNTY FLOOD HAZARD INVESTIGATION

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AREAS OF POTENTIAL INUNDATION

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1000 0 1000 2000

APPENDIX H

COOPERATIVE AGREEMENT
BETWEEN
THE STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
AND
THE COUNTY OF SAN DIEGO

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COOPERATIVE AGREEMENT
BETWEEN
THE STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
AND
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COOPERATIVE AGREEMENT
BETWEEN
THE STATE OF CALIFORNIA, DEPARTMENT OF WATER RESOURCES
AND THE
COUNTY OF SAN DIEGO

This Agreement, entered into by and between THE STATE OF CALIFORNIA, DEPARTMENT OF WATER RESOURCES, hereinafter referred to as the STATE, and the COUNTY OF SAN DIEGO, hereinafter referred to as the COUNTY:

W I T N E S S E T H

WHEREAS, by the State Water Resources Law of 1945 the State is authorized to make investigations of the water resources of the State, formulate plans for the control, conservation, protection, and utilization of such water resources, including solutions for the water problems of each portion of the State as deemed expedient and economically feasible, and may render reports thereon; and

WHEREAS, by said law the State is authorized to cooperate with any county, city, state agency or public district on such water resources investigations and when requested by any thereof may enter into a cooperative agreement to expend money on behalf of any thereof to accomplish the purposes of said law; and

WHEREAS, the County has requested the State to make a cooperative investigation and report on the flood control problems of the major coastal streams of San Diego County;

NOW THEREFORE, it is mutually agreed, subject to the availability of funds, as follows:

1. The State shall perform the work provided for by this Agreement and shall prepare the report and otherwise advise and assist in formulating the flood hazard problems of the County.

2. The work program shall be as set forth in the attached sheet, entitled "Work Program", marked "Exhibit A", and incorporated herein by this reference.

3. The County shall contribute $53,000, which shall be transmitted to the State prior to commencement of the work.

4. The State shall contribute $53,000 from funds appropriated to the Department of Water Resources by Item 256 of the Budget Act of 1960.

5. Funds contributed by the parties shall be deposited in the Water Resources Revolving Fund in the State Treasury for expenditure by the State in performance of the work provided for in this Agreement.

6. The State shall under no circumstances be obligated to expend for or on account of the work provided for under this Agreement any amount in excess of the funds made available hereunder.

7. A statement of expenditures for the fiscal year ending June 30, 1962, shall be furnished the County by the State as soon as practicable after the close of the fiscal year.

8. Upon completion and final payment for the work provided for in this agreement, the State shall furnish to the County a statement of expenditures made under this Agreement, and any balance which may remain of the sum or sums advanced by the County shall be returned to the County.

9. It is mutually understood that the sum of One Hundred Six Thousand Dollars ($106,000) to be made available as hereinbefore provided, is adequate to cover the cost of performing that portion of the work scheduled by the State for performance during the fiscal year 1961-62.

10. Funds unexpended by the State during the fiscal year 1961-62 shall, if necessary, be available for final completion and publication of the report during fiscal year 1962-63.

11. During the progress of this investigation, all maps, plans, information, data, and records pertaining thereto which are in possession of either party hereto, shall be made fully available to the other party for the due and proper accomplishments of the objectives hereof.

12. The work to be done under this Agreement shall be diligently prosecuted with the objective of completing the investigation and report by June 30, 1962, or as nearly thereafter as possible.

13. The County shall be provided with 50 copies of the final report, and the State shall provide copies for distribution to the official archives and principal libraries in the State.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement as of the date hereof.

DATED: June 26, 1961.

Approved as to form and legal sufficiency:

/s/ Mark C. Nosler
Acting Chief Counsel
Department of Water Resources

Approved - Department of Finance

/s/ D. M. Luevano

COUNTY OF SAN DIEGO

By /s/ D. W. Bird

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

By /s/ Paul L. Barnes

Approved as to form

HENRY A. DIETZ
COUNTY COUNSEL

By /s/ Robert G. Perry
Deputy

WORK PROGRAM

The objectives of the work to be performed under this agreement shall be to determine the peak discharges at various points along the major coastal streams, as hereinafter listed, for varying frequencies of occurrence and to delineate the areas inundated under present cultural conditions at each occurrence interval. The work shall be completed in staged sequence for the following streams in the order shown:

1. San Diego River from El Capitan and San Vicente Dams to Mission Gorge
2. Sweetwater River from Sweetwater Dam to mouth
3. San Dieguito River from Sutherland Dam to mouth
4. San Luis Rey River from Lake Henshaw to mouth
5. Otay River from Lower Otay Dam to mouth.

The work necessary to accomplish these objectives shall consist of:

1. Preparation of an inventory and evaluation of existing data and determination of areas requiring collection of additional data
2. Computation of flood flows along the subject streams for varying frequencies of occurrence through investigation of hydrology of the entire watershed contributing to the stream
3. Preparation of maps of areas that would be flooded under present topographic conditions and cultural developments for the various intervals of flood conditions.

Exhibit A

Interim reports shall be prepared on each stream group as completed, to be compiled into a final report covering the entire investigation.

Exhibit A (Cont.)

AMENDMENT NO. 1 TO COOPERATIVE AGREEMENT NO. 860128
BETWEEN THE STATE OF CALIFORNIA,
DEPARTMENT OF WATER RESOURCES, AND THE
COUNTY OF SAN DIEGO

THIS AMENDMENT TO AGREEMENT, entered into by and between THE STATE OF CALIFORNIA, DEPARTMENT OF WATER RESOURCES, hereinafter referred to as the STATE, and the COUNTY OF SAN DIEGO, hereinafter referred to as the COUNTY:

W I T N E S S E T H

WHEREAS, the State and the County entered into an agreement, dated June 26, 1961, providing for the financing and undertaking of an investigation and preparation of a report by the State on the flood hazard problems of the major coastal streams of San Diego County; and

WHEREAS, said agreement provided that the State and County each contribute $53,000 for expenditure by the State in performance of the work provided for in the agreement; and

WHEREAS, said agreement provides that funds unexpended by the State during the fiscal year 1961-62 shall be made available for final completion and publication of the report during fiscal year 1962-63; and

WHEREAS, because of unforeseen delays in staffing and printing, the report cannot be completed and printed in final form until after the end of fiscal year 1962-63; and

WHEREAS, there are presently in the Water Resources Revolving Fund in the State Treasury, funds sufficient to cover costs of completing and printing of the report;

NOW, THEREFORE, it is mutually agreed that the agreement referred to above be hereby amended to provide that any unexpended funds deposited in accordance with said agreement which remain at the end of fiscal year 1962-63 shall be available for final completion and publication of the report during fiscal year 1963-64.

Except as herein amended, all other terms of the agreement between the State and the County shall remain in full force and effect.

IN WITNESS WHEREOF, the parties hereto have executed this amendment as of the date hereof:

DATED: June 25, 1963

Approved as to form and procedures:

/s/ David B. Walker
County Counsel

Approved as to legal form and sufficiency:

/s/ James M. Carl
Counsel
Department of Water Resources

COUNTY OF SAN DIEGO

By /s/ Robert C. Cozens
Chairman, Board of Supervisors

ATTEST: Helen Kleckner
Clerk of the
Board of Supervisors

By /s/ J. Miller
Deputy
Clerk

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

By /s/ Neely Gardner
DEPUTY DIRECTOR ADMINISTRATION

APPENDIX I

BIBLIOGRAPHY

BIBLIOGRAPHY

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